94th Congress, 2d Session } JOINT COMMITTEE PRINT

REVIEW OF NATIONAL BREEDER REACTOR PROGRAM

REPORT

BY THE

AD HOC SUBCOMMITTEE TO REVIEW THE LIQUID METAL FAST BREEDER REACTOR PROGRAM

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY
CONGRESS OF THE UNITED STATES

JANUARY 1976

Printed for the use of the Joint Committee on Atomic Energy

U.S. GOVERNMENT PRINTING OFFICE
58-550 WASHINGTON : 1976

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $2.20

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HON. MIKE MCCORMACK,
U.S. HOUSE OF REPRESENTATIVES,
Washington, D.C., January 30, 1976.

HON. JOHN O. PASTORE,
Chairman, Joint Committee on Atomic Energy, Congress of the United States, Washington, D.C.

DEAR MR. CHAIRMAN: The Joint Committee on Atomic Energy's Ad Hoc Subcommittee To Review the National Breeder Reactor Program has completed its review and prepared a final report. As chairman of this subcommittee, I am pleased to submit the report herewith for your consideration. As you know, all members of the full committee served on the subcommittee.

The purpose of the subcommittee's review was to examine the various concerns that have been expressed and questions that have been raised within the Congress and outside by members of the public with respect to several fundamental issues such as the need for the breeder program, the potential benefits to be realized from it, and the attendant risks associated with ultimate widespread commercial use of breeder reactor technology as a means of generating electricity.

The subcommittee's review was conducted over a period of several months and included the preparation of a questionnaire on several energy issues that was sent to over 90 organizations and individuals, and analysis of the responses thereto, the holding of public briefings and hearings on selected energy and nuclear power topics, and an on-site review of the breeder reactor programs in several foreign countries.

The subcommittee's findings are embodied in the enclosed report, which includes consideration of energy trends, alternative energy options, and uranium resource availability as factors impacting the need and timing of the Nation's breeder reactor program. While I shall not attempt to summarize all the conclusions and recommendations reached, foremost in my mind and deserving of special attention are the following:

1. Continuation of the breeder development program, as a high priority effort, is essential to the energy future of this Nation.
2. The breeder is needed no later than it will become commercially available under current development plans, that is, the early 1990's.
3. Vigorous pursuit of Liquid Metal Fast Breeder Reactor (LMFBR) development at this time, including construction of demonstration plants, is essential to provide adequate information on which to base future decisions concerning commercialization of breeder technology. The collection of this information does not constitute a commitment to future commercialization.
4. An aggressive program of research and development on the safety and environmental impacts of breeder commercialization must be continued as a top priority effort. Our present knowledge and under-

standing of these issues suggests no reason for delaying the breeder program.

5. Substantial reliance on foreign technology beyond the establishment of information exchange agreements is not a satisfactory substitute for development of a breeder reactor industry in the United States.

6. A very substantial review effort on breeder development plans, approach and strategy has been and continues to be made by advisory groups and others. The conduct of such studies should not be allowed to occasion delay in the program.

It should be observed that a number of industrial nations (France, United Kingdom, U.S.S.R., and West Germany), in developing their breeder programs, have reached a policy consensus that is consistent with these conclusions.

The subcommittee's report also makes several recommendations in line with the above conclusions. In essence, these recommendations are that the development of the breeder should be continued with a new sense of urgency, and that the Liquid Metal Fast Breeder Reactor should remain the focal point of this program. The Subcommittee wishes to emphasize that the LMFBR program has been repeatedly designated as this nation's top priority energy program. This has been enunciated by the Executive Branch and confirmed by the Congress. The Subcommittee would like to observe that repetitive studies on this issue will serve little purpose. In fact, they tend to distract Members of Congress and the public from the important challenge facing us, to wit, the solution of problems inherent in the development of the breeder as an essential part of our nation's energy policy.

As a final note I would like to assure you that the Subcommittee in the conduct of its review has made every effort to draw upon all available sources of information, and to provide every reasonable opportunity to those wishing to present oral testimony or furnish written statements for the record of our hearings. In my judgment, the material and testimony presented to the Subcommittee afforded us the opportunity to consider all points of view. Our extensive schedule of public hearings provided the members with the opportunity to explore in depth the views and rationale underlying the positions expressed by witnesses from government agencies, private industry, the scientific community and the public at large.

Of, course, it is never possible to evaluate the future potential of very large programs without being influenced by some subjective judgments. However, a detailed examination of the testimony received and the treatment by the Subcommittee will demonstrate clearly that this report deals with engineering and scientific fact. The Subcommittee members were dedicated to developing the fairest and most rational projections and assumptions that the Subcommittee was able to devise based on the information presented and available to it.

I am pleased to have had the opportunity to serve as Chairman of this Subcommittee. I believe that the Subcommittee Report, the Committee prints of the information received, and the transcript of the hearing record will prove to be valuable reference documents, not only for the Committee and Members of Congress, but for the general public as well. I would like to add that the Subcommittee had the benefit of staff assistance provided not only by the Joint Committee,

but by representatives of the Office of Technology Assessment, the Congressional Research Service of the Library of Congress, the General Accounting Office, the Energy Research and Development Administration, and qualified individuals drawn from the personal staffs of some of the Subcommittee members. All these persons contributed materially to the work of the Subcommittee.

Sincerely yours,

MIKE MCCORMACK,
Chairman, Ad Hoc Subcommittee To Review the National Breeder Reactor Program.

SECTION I

EXECUTIVE SUMMARY

A. ENERGY TRENDS

In its consideration of the subject of energy trends, the Subcommittee focused its attention on total U.S. energy demand in 1985, 2000 and 2020, on corresponding percentage energy growth rates and the expected impact that conservation of energy might have on reducing such growth rates. Of special interest to the Subcommittee was consideration of the electrical energy component of the expected total energy growth rates. The information received in response to the Subcommittee questionnaire and in the oral testimony on this subject was remarkably diverse, perhaps because widely differing scenarios of energy growth over the period studied can be constructed using only a few essential factors. Consideration of even the very reduced rate of energy growth that some witnesses believe may occur makes it evident that because of our dwindling supplies of domestic oil and natural gas a gap in energy supply of considerable magnitude would be projected.

The uncertainties in projections of future electric power consumption were even greater than those of total energy but the electrical component can be expected to grow more rapidly than total energy demand. The great advantage in filling the projected energy gap is that electricity can be produced by using domestic resources of coal and uranium. It seems evident that significant efforts must be undertaken to convert many end uses from petroleum fuels to electric power in order to reduce heavy dependence on imported oil. The extent to which such programs will result in electric power consumption growing more rapidly than total energy is difficult to determine.

Conclusions

After having carefully reviewed the information submitted to it on the subject of energy trends, the Subcommittee concludes that:

1. Although forecasting national energy consumption is an imprecise science, and at present only marginally useful in forecasting energy consumption patterns and production levels for various technologies, there are trends, which taken along with a realistic appraisal of what can be accomplished to alter them within a given time frame, provide a valuable tool for understanding energy requirements for the future.

2. Energy growth rates, both total and electrical, may in the near term be lower than has been seen in the past. However, substantial forces do exist which will prevent these growth rates from declining

A glossary of terms and a list of abbreviations appear on pages 146 and 148 respectively.

precipitously from historical levels, and for sustained periods during the balance of this century. These realities are fundamental to energy planning.

3. A minimal compounded energy growth rate of slightly less than 3.0 percent per year represents a reasonable "best guess" for energy planning purposes. Adjustments in this estimate may be necessary as further data are accumulated.

4. A minimal compounded electrical growth rate of about 5.5 percent per year should be used for planning purposes. This would result in an electrical generating capacity of 550 gigawatts in 1985 and 1230 gigawatts in the year 2000 (average capacity 65%). Recognizing again that these projections are imprecise, they nevertheless provide a basis by which energy policy can be established. (The present U.S. capacity is 430 gigawatts.)

B. THE ENERGY GAP—HOW TO FILL IT

In order to find ways in which to fill the projected energy gap and to determine the possible role of nuclear power in that process, the Subcommittee focused its attention on projected demands for total energy and electrical energy, including the mix of energy sources, the principal limitations for conversion into electricity, the extent to which the U.S. should rely on energy resources imported from abroad, forecasts of nuclear generating capacity in the period 1985 through 2020, and the possible mix of reactor types during that period.

The United States is currently relying on oil and gas for 77 percent of its energy needs, yet these fuels account for less than 5 percent of the Nation's estimated energy resources. There was general agreement in the information and testimony presented to the subcommittee that heavy reliance on oil and gas will have to be curtailed and substitute sources utilized to meet future demands. There was agreement that the major resources available to meet these demands were domestic uranium and coal. Uranium will make its energy contribution through the generation of electricity, while coal can make a significant contribution in a number of energy forms, including the generation of electricity.

In addition to the foregoing, most respondents and witnesses agreed that there was need to pursue solar heating and cooling, solar electric power, geothermal energy and the production of energy from waste materials. Further, most concluded that these potential sources could make a significant contribution only after development and commercialization occurs, and thus they would not reduce significantly major reliance on nuclear and coal generated electric power during the remainder of this century.

There was clear recognition that if the generation of nuclear electric power is limited to reactors now in commercial use, then our Nation's estimated uranium resources will suffice only for the remainder of this century. In order to obtain full utilization of our uranium energy resource, breeders must be developed in a form suitable for commercialization.

The role that nuclear power will play in closing the energy gap will depend on many factors, including the demand for electricity, the availability of coal and its environmental acceptability, and factors limiting the growth in nuclear capacity.

Conclusions

The material reviewed by the Subcommittee indicates that (1) the Nation will be forced to substantially decrease its dependence on oil and gas because these fuel resources will continue to dwindle dramatically even when reinforced by off-shore and synthetic programs; (2) electrical energy will as a result be substituted for direct use of oil and gas wherever practicable; and (3) coal and nuclear power will be the major sources of energy used to generate the increasing amounts of electricity required for the balance of the century.

Recommendations

Because nuclear power must play a significant role in meeting electric demands in the very near future, the Subcommittee believes that every effort should be made now to ensure that nuclear power will be able to fulfill its potential contribution.

C. ALTERNATIVE ENERGY OPTIONS

In its review of the National Breeder Reactor Program, the Subcommittee believed it important to conduct its review in the context of examining which alternative energy options are available or could be made available to satisfy national energy needs. Most persons and organizations who have studied the energy supply/demand situation recognize the need for this country to utilize a variety of existing energy sources as well as to develop potential sources for future use.

From the inception of the civilian nuclear power program, the Joint Committee on Atomic Energy has always undertaken to evaluate the utilization of nuclear power in the light of other energy options, either existing or under development. This approach is probably most notably exemplified by the Joint Committee's review of the Atomic Energy Commission's 1962 report, "Civilian Nuclear Power—A Report to the President". This comprehensive program evaluation and plan for the future was reviewed in depth by the Joint Committee during public hearings held in the Spring of 1963*. The Committee considered it important to determine the need for and feasibility of the civilian nuclear power program before embarking on an extensive development program with the concomitant expenditure of large sums of public funds.

A principal conclusion of the AEC study which was endorsed by the Joint Committee was that:

> We have seen from earlier discussions * * * that even absorption of the total power industry by nuclear installations would still leave no dearth of markets for fossil fuels. . . . Furthermore, the electric industry itself is growing at such a rapid rate that no possible growth of nuclear installations could prevent power generation from consuming greatly increasing amounts of fossil fuels for several decades * * *

*Development, Growth, and State of the Atomic Energy Industry, Joint Committee Print, Parts 1 and 2, February and April 1963.
See also the 1967 Supplement to the 1962 Report to the President, appendix 13, p. 253, Joint Committee print, Nuclear Power Economics—1962 through 1967, February 1968.
See also Understanding the National Energy Dilemma, Joint Committee print, August 1973.

In similar fashion the Subcommittee in this recent review has sought information from respondents and received oral testimony concerning alternate energy sources.

The principal alternate energy sources reviewed by the Subcommittee were solar and geothermal power. Support for development of these energy options was given both by those responding to the Subcommittee's question set and by those giving oral testimony, including both supporters and opponents of the U.S. civilian nuclear power program. The projected contributions that these energy sources could make in meeting the energy demand for future years varied widely depending on those making the projection. Virtually all witnesses agreed that the range for the year 2000 was between 4 percent and 10 percent of our total energy needs.

Various problems were noted that would need resolution before widespread use of a new energy option would be possible. Problem areas noted for solar power were the need to develop cheaper, more durable collectors, heat transfer and storage systems; the need to reduce the cost of the photovoltaic conversion systems by a factor of 100 to 1000; and the protection of collector systems from storm damage and collection of dust and dirt. The large commitment of land for collection systems was also noted. These are all areas being pursued in the development program.

With respect to geothermal energy, the different methods of providing and using geothermal energy were discussed. Environmental effects such as surface and ground water quality impairment and air emissions were noted. Other factors hindering early development of geothermal power that were noted were lack of assurance of the feasibility of profitable production of electricity over the life of the plant, capital requirements and legal problems over ownership rights. These areas are also being addressed in the ERDA R. & D. program. From discussions with government officials in charge of the program, solar advocates and nuclear critics, the general view was that both the breeder and other energy options, such as solar and geothermal, should be developed and that funds for development of all feasible energy sources are expected to be available.

Conclusions

Based on testimony from the ERDA and from a number of other experts, the Subcommittee concludes that energy production will be as shown in Fig. 3 on page 39.

The Subcommittee strongly endorses the substantial increases in funding for alternative energy options, including solar and geothermal power, recently approved by the Congress. The Subcommittee accepts the ERDA projections for the rate of commercialization of alternative energy sources for meeting future energy needs. The Subcommittee notes, however, that even if these projected energy contributions from solar, geothermal and other alternative technologies were to be doubled our fundamental conclusions regarding the need for nuclear power would not change significantly. (Waste conversion is not included in this assumption as waste is a finite resource and cannot be arbitrarily doubled.)

Recommendations

The Subcommittee recommends continued vigorous research and development and funding of alternative energy options, maintaining at all times a realistic perspective of their potential.

D. URANIUM RESOURCE AVAILABILITY

Uranium is the primary fuel used by present day light water reactors. Its availability is a critical element in the debate over the need for breeder reactors and the timing of their introduction into commercial use by the electric utility industry.

In the material reviewed by the Subcommittee only ERDA and EPRI presented independently developed numerical projections. ERDA projects that 3.6 million tons of uranium will be available, at a production cost of $30 a pound or less. ERDA also projects that there is another 13 million tons of uranium at economic and environmental costs which ERDA and others believe might well preclude the use of this material. ERDA engineers and geologists independently develop resource projections based on such inputs as industry data, field examinations and available geologic reports. The majority of those presenting information to the Subcommittee cited ERDA's projection as the most reliable and the one that should be used to plan our energy programs.

If ERDA's recent estimates prove correct, the size and composition of the resource base have serious implications for the non-breeder reactor power program. Information provided to the Subcommittee indicates that more than the approximately 700,000 tons (620,000 of reserves and 90,000 of byproduct) of reasonably assured reserves will be needed over the lifetime of reactors presently operating, under construction, or on order. Plants that will be contracted for from now on will depend for fuel on "potential resources" which have not as yet been discovered or verified. Several respondents reported that at some time during the 1990's all of the "potential resources" will also have been committed to the lifetime needs of new reactors. If converter reactors are to be built after that time, they will depend for fuel on either uranium which has not yet been projected to exist as "potential resource", higher cost uranium from low grade ore deposits, or recycled plutonium.

In an analysis done for the Electric Power Research Institute (EPRI) Milton F. Searl projected that there is a 50 percent chance that there are more than 13.2 million tons and a 5 percent chance that there are more than 28.9 million tons of uranium in the United States. His forecast is based on an extrapolation from ERDA data to obtain the expectation of finding a given amount of uranium below a cost of $100/pound. Searl's forecast is mentioned in the NRDC publication "Bypassing the Breeder" as the forecast which NRDC subscribes to. "Bypassing the Breeder" is frequently cited by those opposed to the breeder as part of their basis for believing the breeder should be postponed or abandoned.

Several witnesses expressed their subjective view that uranium resources will exceed the amounts which ERDA projects. These estimates did not include numerical projections and did not appear to be based on independent analysis.

Since the ERDA and Searl estimates suggest different decisions on the need and timing of breeder reactors, there is a need to determine which of these two estimates is closer to being correct. Unfortunately mineral forecasting techniques are not reliable enough to be able to project with certainty which projection is more nearly correct.

The policy maker, working with imperfect knowledge, must select the resource estimate he will rely upon based on the reliability of the forecasting technique, the track record of mineral forecasting, and the consequences of an erroneous choice. EPRI, for whom Searl made his forecast, believes the ERDA projection is prudent and a reasonable basis for long-range planning. Most of those who expressed views on this topic to the Subcommittee agree with EPRI in this regard. In relation to the track record of forecasting techniques, the recent 75 percent reduction of forecast oil reserves at a time when rising oil prices and the embargo made the existence of these reserves so important, indicates how risky it can be to base policies upon imprecise resource predictions. The consequences of an incorrect decision such as postponing breeder development based on a high estimate of uranium resource which later turns out to be unavailable, would probably include reduced economic growth, increased unemployment, and more costly energy production.

Conclusions

The Subcommittee believes that the ERDA forecast of 3,600,000 tons of uranium at a cost of $30 or less per pound is the most prudent projection on which to base energy plans. It is recognized that these numbers may change as the findings of the National Uranium Resource Evaluation program become available.

The Subcommittee concludes that the uranium supply forecast by ERDA will be inadequate to provide for the nuclear power projected in this report beyond the mid 1990's. The utilization of the breeder concept would increase the energy potential of the presently projected 3.6 million tons of uranium such that it would become equivalent in energy output to about 126 million tons of low cost uranium, an amount of nuclear fuel sufficient to supply nuclear powerplants for centuries.

Recommendations

The Subcommittee recommends that the ERDA vigorously pursue its National Uranium Resource Evaluation Program to establish projections of the uranium resource of this Nation with the greatest possible accuracy.

This Nation should also pursue technological options which will extend the energy potential of our uranium supply.

E. NEED AND TIMING OF THE BREEDER PROGRAM

In recognition of the likely inability of uranium supplies to economically support the future energy load projected for nuclear power, this Nation has had a breeder reactor development program underway for over 25 years. The type of breeder reactor that is generally considered the most advanced and to possess the greatest likelihood of commercial development is the Liquid Metal Fast Breeder Reactor

(LMFBR). An LMFBR development program is in progress with the objective of establishing a broad technological base leading to a competitive commercial industry. An essential element of this program is the construction of a mid-sized demonstration plant, the Clinch River Breeder Reactor (CRBR).

In view of the concerns that have been expressed in Congress and by the public with respect to various aspects of the LMFBR program, the Subcommittee undertook to examine the need for the program, and its potential benefits and risks. In the public hearings and other information collection activities conducted by the Subcommittee, the overwhelming consensus was that the LMFBR is needed, and that this need is urgent. A minority group, generally known to oppose nuclear energy, asserted that the breeder was not needed.

The Subcommittee was impressed that those Government agencies with responsibilities for planning or providing for the Nation's energy needs supported the urgent development of the breeder, as did almost all industrial or utility organizations queried. The main reason offered in support of the need for a commercial breeder on a timely basis was its ability to provide sufficient fuel for future electrical generating requirements. In addition, many proponents of the breeder noted its attractiveness from a cost-benefit basis, i.e., future projected savings in fuel costs by the breeder are expected to far outweigh development costs.

With regard to uranium reserves, the basic argument is that the limited amount of "assured" and "potential" reserves (3,600,000 tons of U_3O_8 in the United States) will be fully committed to "burner" reactors, such as the light water reactor, by perhaps the mid-1990's depending on the energy growth rate, plant capacity, and other factors. No additional reactors of this type could be built after this date unless additional uranium resources are found or low grade ores with their accompanying higher costs and environmental impacts are used. A breeder reactor, on the other hand, would permit the extraction of up to 50 times as much energy from these uranium resources, thereby extending our nuclear fuel supplies from decades to centuries.

With regard to cost-benefit analysis, the basic argument is that the use of breeder reactors will avoid reliance on low grade, high cost uranium ores, with substantial resultant savings in fuel costs which will be passed on to consumers. These savings are estimated, under all but the most pessimistic conditions, to be considerably greater than development costs of the LMFBR program. The net savings would, according to these arguments, reach \$150 billion by the year 2020, as well as substantially reduce the requirements for mining and enriching uranium.

The Subcommittee also heard testimony and received information to the effect that the need for the breeder had been overstated, and that the projected benefits were not to be had. In general, those groups or individuals opposing the breeder were found to do so based on the same arguments that proponents cite to favor its development, but the opponents generally place a different interpretation on the factors cited above. For example, the opponents suggest that development costs will outweigh savings in fuel costs, (i.e., that cost benefit analysis supports the abandonment of the breeder rather than its development), that AEC–ERDA estimates of uranium resources are too

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conservative, and that substantial quantities remain to be discovered at economical prices in this country, that energy demand will be less than projected by breeder proponents in future years, and that safety and environmental problems are beyond man's control.

A corollary question considered by the Subcommittee was, assuming a breeder reactor is needed, whether or not this country should continue to put its major effort on the LMFBR, or if more (or less) effort should be devoted to alternate breeder reactor concepts. Again, respondents were essentially unanimous in agreeing that the LMFBR should continue to be the focus of breeder efforts and receive top priority.

The Subcommittee also examined whether or not the overall LMFBR program objectives, content and approach are correct, and what steps can be taken to minimize the costs of the program, and improve performance with respect to program schedules. With regard to overall objectives and approach, the great majority of respondents was again enthusiastic about the program goals and the means proposed to achieve them. A few respondents, who as noted before, are generally viewed as opposing nuclear energy, found the whole program premature and ill-advised. They recommended steps such as successful operation of the FFTF before a demonstration plant is built, if at all.

The placement of greater reliance on foreign technology was suggested as a means of improving program performance and reducing costs. While the surface advantages of this approach are evident, several disadvantages were also pointed out, such as the state of dependence the U.S. might be placed in (such as now exists on foreign oil), failure of the U.S. to develop its own industry, undesirable impact on our balance of payments situation, and the need for foreign designs to be modified to meet U.S. safety and licensing requirements.

Other questions examined by the Subcommittee included the total R. & D. costs for the LMFBR and their means of recovery, the predicted capital costs of commercial LMFBR's and the methods to provide that capital, and the overall issue of whether or not the LMFBR would be economically viable. The general consensus of information presented was that the $10.6 billion ERDA figure for the total LMFBR research, development and demonstration program was a reasonable estimate, although a few respondents voiced strong feelings that previous inabilities to meet cost estimates meant the figures would go much higher.

With regard to timing for the LMFBR, the consensus was that the breeder is needed by about the time it would become commercially available under current development plans, i.e., the early 1990's. Several witnesses suggested this timing should be accelerated, noting that if energy demand returns to near-historical levels, the breeder may already be too late. A substantially different minority view was also presented to the Subcommittee, specifically that based on the premise that future energy demand would be lower than that proposed by AEC-ERDA, and that since there is a reasonable "likelihood" of additional uranium resources being identified, the need and timing for the LMFBR is uncertain at best.

With regard to the subject of LMFBR commercialization, the Subcommittee examined the issue of whether or not proceeding with the LMFBR R. & D. program now, specifically with the CRBR project, represents an irreversible commitment to commercialization.

It was found that any judgement on whether or not a technology option is exercised (i.e., a number of plants of that type are built) will depend on the relative technical and economic merits of that option in comparison with other available options. The *decision* on exercising an option will rest primarily with the utility industry, rather than the Government, and it was therefore reported that proceeding with the current LMFBR program does not present a commitment to commercialization, nor does it prejudge any decision concerning the eventual commercialization of the technology.

Conclusions

The Subcommittee concludes:

1. Continuation of the breeder development program, as a high priority effort, is essential to the energy future of this Nation.

2. The breeder is needed no later than it will become commercially available under current development plans, i.e., the early 1990's.

3. Vigorous pursuit of LMFBR development at this time, including construction of demonstration plants is essential to provide adequate information on which to base future decisions concerning commercialization of breeder technology. The collection of this information does not constitute a commitment to future commercialization.

4. An aggressive program of research and development on the safety and environmental impacts of breeder commercialization must be continued as a top priority effort. Our present knowledge and understanding of these issues suggests no reason for delaying the breeder program.

5. Substantial reliance on foreign technology beyond the establishment of information exchange agreements is not a satisfactory substitute for development of a breeder reactor industry in the U.S.

6. A very substantial review effort on breeder development plans, approach and strategy has been and continues to be made by advisory groups and others. The conduct of such studies should not be allowed to occasion delay in the program.

Recommendations

1. The breeder program should be continued with a new sense of urgency, and the LMFBR should remain the focal point of this program. In addition, other breeder options should be pursued.

2. The LMFBR development schedule should be reexamined by the ERDA and continually reoptimized in accordance with projected need dates. Urgent consideration should be given now to final steps and facility requirements for bringing the breeder program to commercialization at the earliest possible time.

3. The Subcommittee believes that the time has come to end the discussion over whether or not this Nation should have a breeder research and development program. Rather, national attention should be turned toward solving the outstanding problems associated with the program and its eventual commercialization.

4. The ERDA should lend greater emphasis to the establishment of technical information exchange agreements with foreign countries who are also actively developing the LMFBR.

5. The tendency within the Federal Government towards duplicative and redundant reviews of nuclear power and the need for the breeder reactor should be recognized and held to a minimum. Further reviews should be on narrower issues, such as means for improving cost and schedular performance. Their emphasis should not be on the issue of "should we do the job", but on "how best to get the job done".

F. CLINCH RIVER BREEDER REACTOR (CRBR)

The Clinch River Breeder Reactor project has been undertaken with the intention of demonstrating technical performance, reliability, maintainability, safety, environmental acceptability, and economic feasibility of a liquid metal fast breeder central station electric power plant in a utility environment. It is to be a 350 MWe (net) reactor plant intermediate in thermal size between the Fast Flux Test Facility now under construction and the Near-Commercial Breeder Reactor planned for construction and operation later in the overall LMFBR program.

Some witnesses before the committee suggested a delay in schedule for the CRBR which they point out would allow for redesign of the plant to bring it more in line with current technology. They would first have ERDA complete the Fast Flux Test Facility, an irradiation and components testing reactor, and carry out the two projects in series rather than on the present overlapping schedules. Others suggested that the CRBR be cancelled and that this country pursue the use of foreign breeder technology as illustrated by LMFBR demonstration plants now operating in France and elsewhere. Proponents of the CRBR and ERDA's overall LMFBR program warned that there had already been schedule slippage in the CRBR project and any restudy of design would result in additional delay, placing us even further behind other nations. They believe that much will be learned by operation of the reactor as currently designed.

Some witnesses before the Subcommittee questioned the propriety of the size selected for the CRBR, suggesting that it might be made larger. Proponents of the CRBR point out that in thermal rating it is about two and one-half times the size of FFTF and would be about one-third to one-fourth the size of the NCBR. In their view it would provide a proper intermediate step between the FFTF and the NCBR.

In the summer of 1972 when the AEC furnished the Program Justification Data Arrangement for the CRBR the total cost of the project was estimated to be $699 million. In March of this year ERDA submitted revisions to that arrangement, including a new estimate of cost—$1.736 billion. ERDA attributes the increase in cost to be primarily the result of a better definition of project scope, including design changes, the effects of inflation, cost trends in the utility supply and manufacturing industry, and increased environmental and licensings constraints.

Conclusions

The Subcommittee emphasizes that the CRBR is an important and necessary element in the orderly progression of research, development and demonstration for a responsible LMFBR program. The Subcommittee also believes that the projected operational schedules of the FFTF and the CRBR project permit a proper use of design experience and allow for an efficient utilization of scientific and engineering manpower.

Recommendations

The Subcommittee recommends that the ERDA and its industry partners in the CRBR project make every reasonable attempt to adhere to the present schedule for design, construction and licensing review of the CRBR. If any future turn of events indicates to the project participants an opportunity for improvement in the schedule for the CRBR's availability date, the matter should be pursued and the Joint Committee so notified.

G. SAFETY AND ENVIRONMENTAL CONCERNS

The main safety and environmental issues addressed were reactor safety, plutonium toxicity, radioactive waste management, nuclear material safeguards and environmental effects of alternate energy sources.

1. REACTOR SAFETY

The principal safety issue dealt with the likelihood and potential consequence of a major nuclear accident. Opponents of nuclear power expressed the view that the consequences of a major nuclear accident would be so severe that development of the breeder should be slowed or halted. Proponents argued that the low probability for initiating and completing an accident sequence leading to major equipment failure, coupled with the design of the plant to provide protection to the public over a wide range of assumed accident conditions, made nuclear power safer than other means of producing economic energy today.

Conclusions

Reactor safety questions noted during the Subcommittee's study appear amenable to technical resolution. The Subcommittee notes with satisfaction that a comprehensive research program is being carried forward to assure that every conceivable hazardous circumstance or condition that might arise in a Liquid Metal Fast Breeder Reactor is being considered in advance, and that no credible situation or accident has been hypothesized to date for which adequate design and safety features are not under consideration.

Recommendations

The Subcommittee recommends that the ERDA, NRC, reactor vendors and utilities continue to give close attention to the development of safe breeder reactor designs and carry out the necessary experimental programs to substantiate all important elements of those designs.

2. WASTE MANAGEMENT

Possible dangers from high-level radioactive wastes and postulated deficiences in waste disposal technology, together with the moral issue of imposing control of these wastes on future generations, are reasons frequently advanced in opposition to nuclear power in general and to the breeder in particular. On the other hand, the AEC and now ERDA have had programs underway for some time to further develop and demonstrate economically attractive, environmentally accept-

able and technologically feasible long-term approaches to waste management.

Conclusions

The Subcommittee concludes that, on the whole, the potential difficulties which may be encountered in the radioactive waste management program do not pose risks to the public of such magnitude that this Nation should forego its nuclear energy program, including the development of a breeder reactor. Clearly much remains to be done to demonstrate and finalize the technology for long-term waste management, but the problems involved are not insurmountable.

Recommendations

1. In view of the fact that radioactive waste management requirements for breeder reactors will be essentially similar to those for light water reactors, the Subcommittee recommends that the ERDA vigorously pursue its research, development, and demonstration program for waste management and storage. In making this recommendation, the Subcommittee recognizes that the technology required for waste management is largely in hand and that the critical delays being experienced today are primarily administrative and regulatory. Public understanding of the nuclear energy program and the closing of the fuel cycle including waste management are critically important factors which must be addressed at once.

2. The Nuclear Regulatory Commission should maintain close cognizance of waste management research, development, and demonstration programs and provide, in timely fashion for the use of the nuclear industry, approved criteria intended to guide the users and the public as to the acceptability, from a public health and safety viewpoint, of the proposed methods of waste storage and disposal.

3. SAFEGUARDS

Among the issues raised concerning nulcear power and the development and utilization of the breeder, that of nuclear safeguards is the most subjective. The Subcommittee sees safeguards as having the potential to keep dangers feared by some analysts within bounds acceptable to society. Developing this capability will require continuing support and attention by both the Federal agencies and the Congress. As for zero risk from theft and sabotage, this cannot be assured any more than for other human activities. There will always be some residual risk.

Conclusions

The Subcommittee concludes that:

1. The chances of successful diversion of a significant quantity of plutonium from the nuclear fuel cycle by an individual or small group for terrorist purposes are extremely small.

2. There can be no absolute guarantee against theft of nuclear materials by a well-organized and equipped group willing to accept casualties and possible radiological injury incurred by inadequate handling of these materials.

3. Because of the potential consequences of diversion of nuclear materials for clandestine purposes safeguards systems must be devised and implemented in a manner which will minimize the possibility of success of such an undertaking.

4. The suggestion that the imposition of appropriate safeguards measures for the nuclear fuel cycle threatens the civil liberties of the people of this or any other country does not appear warranted.

Recommendations

The Subcommittee recommends that the ERDA and the NRC work closely together to define precisely safeguards risks and the goals to be accomplished in order to ensure the security of nuclear materials. In so doing, the ERDA and the NRC should make maximum use of the expertise and knowledge resident in sister Federal agencies.

4. PLUTONIUM TOXICITY

The most serious problem raised regarding plutonium toxicity was the claim that the radiation protection guide for plutonium should be made more conservative by a factor of 115,000 (the hot particle hypothesis). Witnesses appearing on this topic reported on a considerable number of reviews that had been undertaken on this issue by experts in the field. The overwhelming consensus of these groups is that the present analytical methods are satisfactory and that a reduction of 115,000 in the protection guide for plutonium is without justification.

Conclusions

The Subcommittee finds that:

1. Since its discovery more than three decades ago, countless man years of diligent research work have been brought to bear on the subject of plutonium toxicity, both in this country and throughout the world. It is well recognized that carcinogenic properties of inhaled plutonium require that the high standards of care in the handling of this material which have been traditionally practiced for the past 30 years must be maintained.

2. The capability of inhaled plutonium within a specific particle size range to produce lung cancer has been demonstrated in experimental animals. There are no cases on record of human lung cancer attributed to exposure to plutonium notwithstanding the fact that a number of early workers in the U.S. military program were accidentally subjected to lung doses significantly above levels prescribed in radiation protection guides.

3. Approximately five tons of plutonium-239 have been injected into the atmosphere primarily in the Northern Hemisphere by atmospheric weapons testing. About four tons of this have fallen to the surface of the earth. Every human being in the Northern Hemisphere is carrying a measurable amount of this plutonium in his body. Although these atmospheric weapons tests occurred more than a decade ago, there is no indication that this plutonium deposition has caused any untoward health effects.

4. The theory that plutonium would be extraordinarily dangerous in the form of "hot particles" in the lungs has been thoroughly analyzed by competent and independent scientific bodies both in Great Britain and the United States and found to have no substance in scientific fact.

Recommendations

The Subcommittee recommends that:

1. The ERDA in the conduct of its activities and the NRC in its licensing and enforcement actions continue to require the high standards of plutonium protection that have been maintained in the past.
2. The ERDA and other agencies of Government concerned with the conduct of health research continue efforts intended to improve our understanding of the biological effects of human and animal exposure to plutonium and other transuranic elements.

5. ENVIRONMENTAL EFFECTS OF ALTERNATE ENERGY SOURCES

The Subcommittee reviewed information submitted and testimony received on the environmental effects of alternate energy sources. The projected expanded use of coal was cited as the alternative likely to pose the most severe environmental impacts. The use of oil shales and tar sands were also noted as having potential environmental impacts of some formidable proportions.

Conclusions

The Subcommittee concludes that any alternative energy source is likely to bring with it environmental effects objectionable to some part of our society. Therefore, it would be unwise to assume that alternative energy technologies which have not yet been fully studied will be without environmental impacts of some consequence.

·Recommendations

The Subcommittee recommends that the ERDA and other elements of the Federal Government concerned with potential detrimental public health effects resulting from energy generation and usage continue to pursue, and in some relatively new areas initiate pursuit of, programs which will permit proper assessment of the environmental impact of the generation of energy from all sources and by all mechanisms which may affect the general public.

6. ENERGY CENTERS

The idea of energy centers has attracted interest and support as one way to reduce risks of theft of nuclear materials and to increase protection of nuclear facilities against sabotage. The concept is one of collecting in one location the industrial operations involving fissionable materials and radioactive waste processing so that risks can be reduced through decreased transportation, common physical security, and other savings in management and control.

Conclusions

The Subcommittee concludes that:

1. Certain benefits can be reasonably expected to accrue from the establishment of Federally-owned energy centers in various electric distribution regions throughout the country.

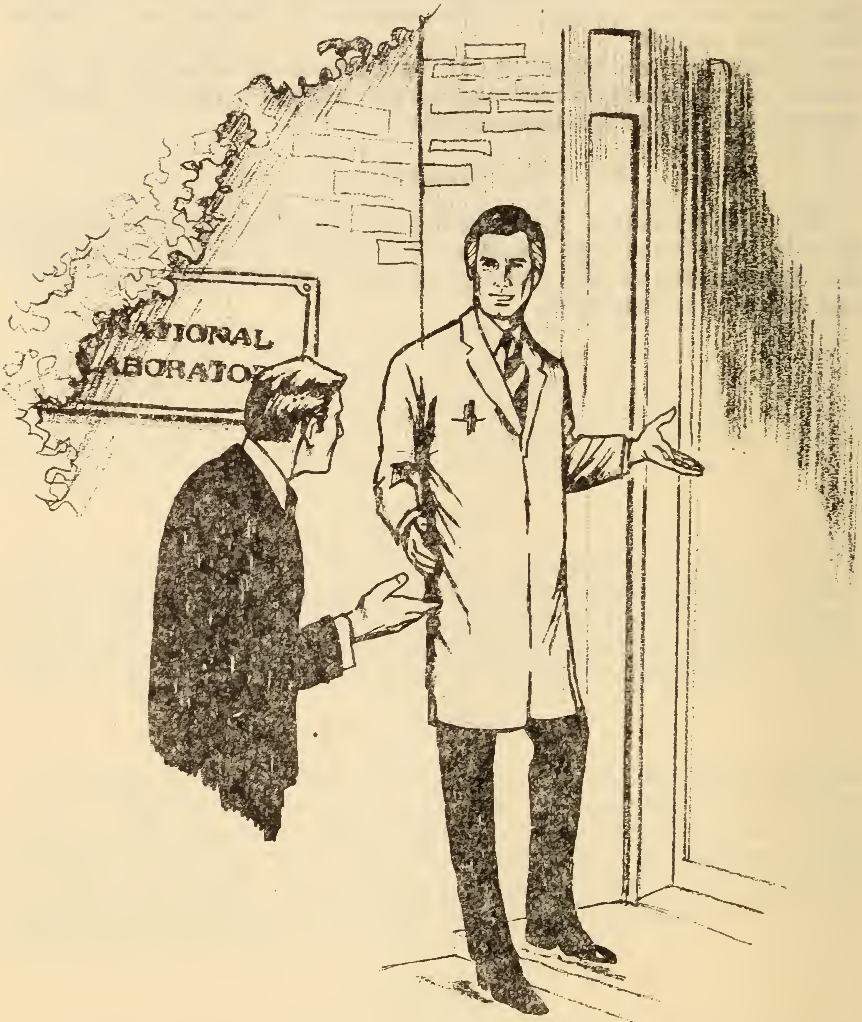
2. This concept does not envision requiring that all energy production from nuclear energy or other sources be limited to production from such centers.

3. Energy centers would be ideal centers for development of alternative energy concepts and might prove attractive sites for the production of energy from these sources.

Recommendations

The Subcommittee recommends that serious consideration be given to legislation that would create energy centers. Careful study and examination of this concept by State and Federal governments and industry is warranted.

A CONGRESSMAN INTERVIEWS A SCIENTIST[1]



A CONGRESSMAN INTERVIEWS A SCIENTIST

CONGRESSMAN. Mr. Scientist, just what is a nuclear breeder anyway?

SCIENTIST. A breeder is a type of nuclear power plant that produces more fuel than it consumes.

CONGRESSMAN. That sounds like perpetual motion. How does it work?

[1] Narrative prepared by Subcommittee; illustrations prepared by ERDA at request of Subcommittee.

SCIENTIST. It isn't really perpetual motion. A breeder makes usable fuel out of that part of the uranium which normally has no value. You see, more than 99% of all uranium, as it occurs in nature, is no good for fuel as it is—we call that part Uranium 238. Less than 1% of naturally occurring uranium is Uranium 235. That's the part that the "fissions" (splits into two pieces). That releases the energy to make heat for producing electricity.

Now, each nucleus of Uranium 235 gives off two or three neutrons when it fissions, and most of these are used to keep the chain reaction going. Some of these neutrons, however, combine with the Uranium 238, which, instead of fissioning, takes a couple of intermediate steps and becomes Plutonium 239, which is extremely valuable because it, like Uranium 235, is a fuel.

In an ordinary "light water" nuclear plant (like those in use today) about 65 plutonium (fuel) atoms are produced for each 100 atoms of Uranium 235 that are used up. Now, in a breeder reactor, we simply "tune" it differently by substituting a liquid metal (such as sodium) as the coolant instead of water, and by making a few other changes. The result is that for each 100 atoms of Uranium 235 used up, we can make about 120 atoms of Plutonium 239.*

CONGRESSMAN. So a breeder is just a nuclear plant that makes more plutonium for fuel that it uses of uranium as fuel. Is that right?

SCIENTIST. Generally, yes. But there are other kinds of breeders, too. One of them makes Uranium 233 (which will also work as a fuel) out of naturally occurring Thorium 232. There are other approaches which may work, and we hope to know more about them in five to ten years.

CONGRESSMAN. Well, why do we have to make fuel anyway? Don't we have enough naturally occurring uranium?

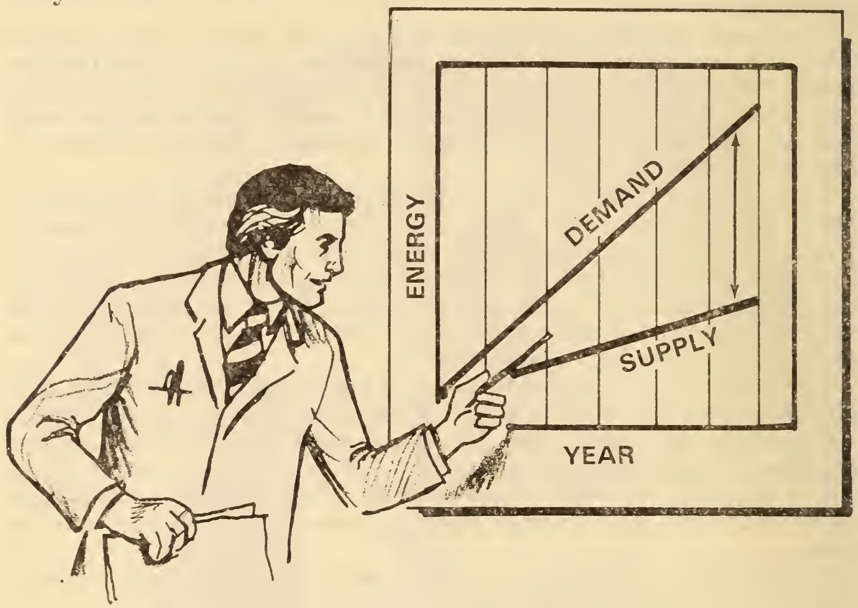
SCIENTIST. No, we don't. At least we think we don't. Our best calculations are that we have enough low-cost uranium to fuel all plants built until sometime in the 1990's, for their entire lifetime. Unless we find vast deposits of high-grade uranium between now and then (preferably within the United States), we will be unable to continue building the type of nuclear power plants we are relying on today.

CONGRESSMAN. I guess that gets us back to a basic question. Do we really need nuclear power in the first place?

SCIENTIST. Yes, we do. Right now, 75% of all of our energy comes from petroleum and natural gas, most of which will be gone by the end of the century. It is important to recognize that these fossil fuel resources have other important uses and should not be used up indiscriminately in the generation of electricity. Further, even with a spectacularly successful conservation program, our energy consumption will continue to grow. The only fuels available during this century to fill the gap between growing demand and declining supplies are coal and uranium. We must rely heavily on both because neither one alone can supply our needs. There is no way that this nation can maintain its energy supplies, its economic stability, its defense posture, or its standard of living without a nuclear energy program.

*See appendix 6 for additional discussion and schematics of nuclear reactor technology.

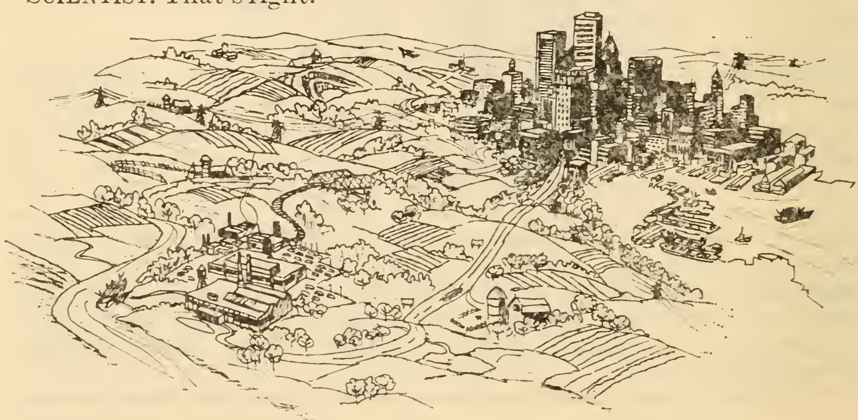
Environmental protection, upward mobility for minority groups, and acceptable employment levels all depend upon having enough energy. Only coal and nuclear power together can meet the energy demand the remainder of the 20th century. We will need energy from these sources even with an ambitious and successful energy conservation program, and even if we had zero population growth starting today.



WE HAVE AN ENERGY GAP—HOW WILL IT BE FILLED?

CONGRESSMAN. So what you are saying is that we need the breeder to make fuel for nuclear energy and we need nuclear energy to maintain our standard of living, employment, national defense, and so on?

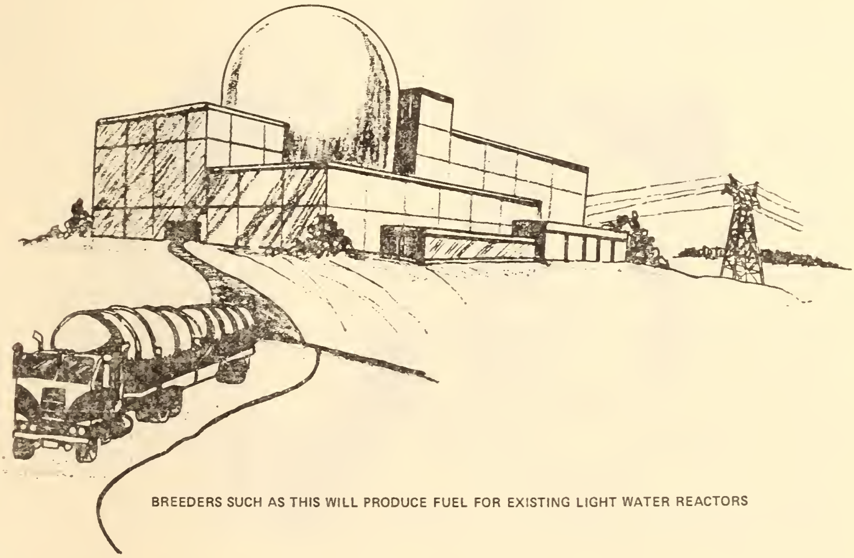
SCIENTIST. That's right.



JOBS, ECONOMIC STABILITY, DEFENSE POSTURE DEPEND ON AN ADEQUATE ENERGY SUPPLY

CONGRESSMAN. But, I understand that breeder reactors will produce very little electricity during this century. If that's the case, why must we build them now?

SCIENTIST. You understand correctly. We will have only a few breeders on the line by the end of this century. Their primary purpose, however, will be in guaranteeing a fuel supply for the hundreds of ordinary nuclear power plants that will be supplying our energy at that time. Assuring that fuel supply is the most important role for the breeders during this century; supplying electricity is secondary.



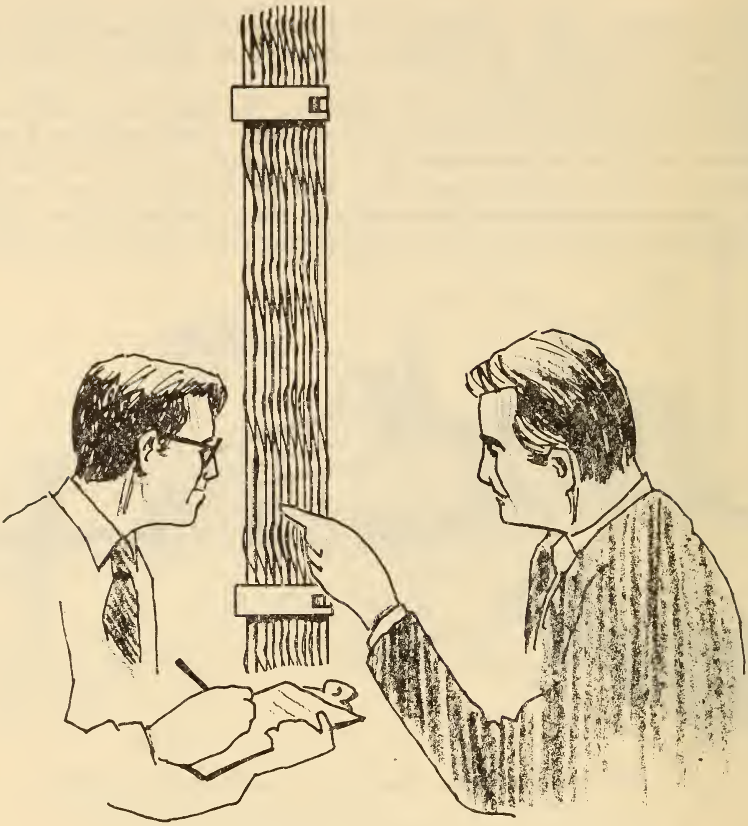
BREEDERS SUCH AS THIS WILL PRODUCE FUEL FOR EXISTING LIGHT WATER REACTORS

CONGRESSMAN. Well then, when will we start to build breeders and how many will we build?

SCIENTIST. That's somewhat uncertain. What we need to do now is to complete our research, development, and demonstration programs so that we will be able to make intelligent decisions ten to fifteen years from now about how we shall proceed. As with light water reactors, solar and geothermal power, energy conservation, and other energy technologies, the U.S. Energy Research and Development Administration, working with private industry, will carry technologies through the demonstration stage, but then the relevant sector of society must decide for themselves on commercialization of the technologies. For example, utilities must decide how many breeders to build, when, what kind, and so on.

CONGRESSMAN. Will breeders be licensed by the Nuclear Regulatory Commission?

SCIENTIST. Yes, of course, and the same high standards for safety that have been required for today's nuclear power plants will be utilized.



NUCLEAR REGULATORY COMMISSION INSPECTOR EXAMINES BREEDER FUEL-ASSEMBLY

CONGRESSMAN. Are breeder reactors safe? Can they blow up?

SCIENTIST. Breeder reactors can be designed and constructed to be extremely safe, possibly even safer than the light water reactors we use today. Nothing in our world is ever absolutely certain but it appears that you would be a lot safer living your entire life at the gate of a breeder reactor than you would driving around the block in your car

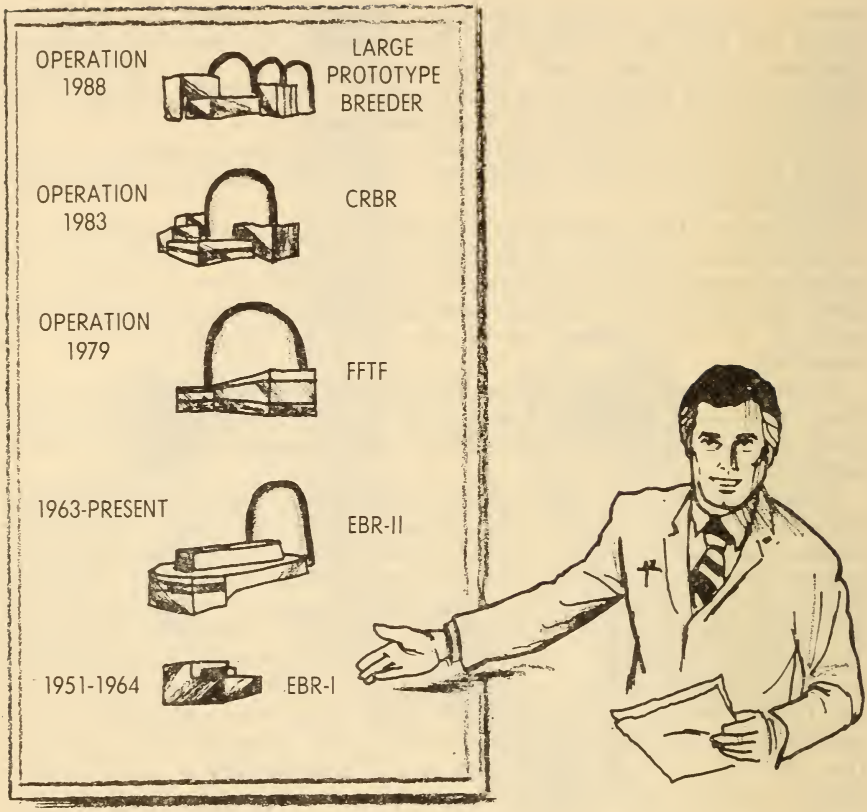
once, or smoking a single cigarette, or taking a single hot bath, or riding one floor on an elevator. Thousands of the world's scientists, doctors, pathologists, and geneticists are living and raising their families in the vicinity of nuclear power plants. Their actions show their confidence in the safety of nuclear power.

CONGRESSMAN. What about some of the other problems I hear about breeder reactors—plutonium, waste disposal and safeguarding of nuclear fuel?

SCIENTIST. These problems and others relative to the safety and environmental impacts of breeder reactors must be addressed by vigorous research and development programs. However, we do know a good deal about these subjects now, and so far this knowledge does not cause us to believe that the breeder program should be delayed or cancelled.

CONGRESSMAN. I am confused about what we are doing right now. You talk about building breeders in the future, but we have just authorized and funded the "LMFBR" in Tennessee. Isn't the LMFBR a breeder?

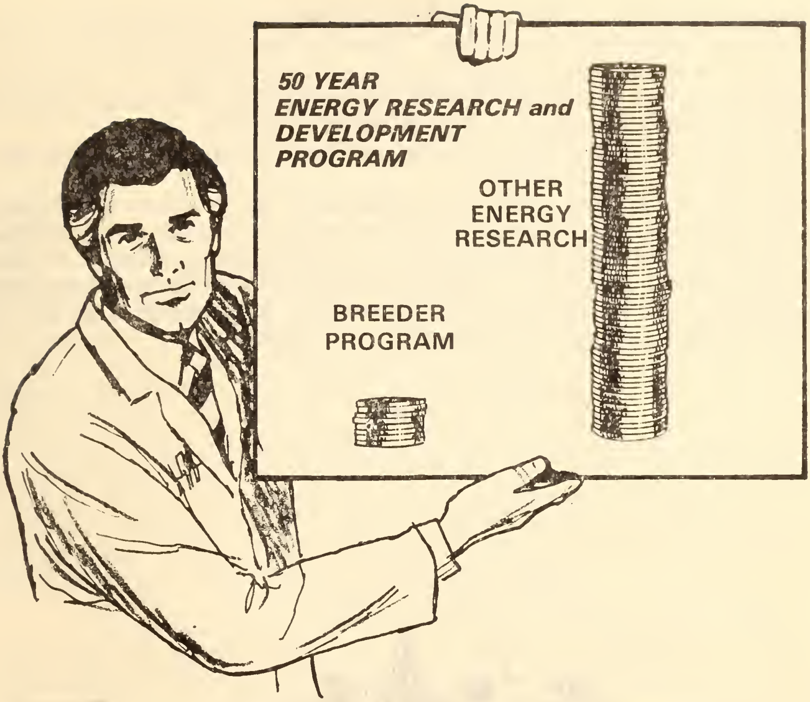
SCIENTIST. Yes, it will be when it is completed about 1983. LMFBR stands for "Liquid Metal" (that means it will be cooled with sodium instead of water). "Fast" (that means the neutrons have a higher energy level in the breeder, than in the light water reactor). "Breeder Reactor"—the plant to be constructed in Tennessee, called the Clinch River Breeder Reactor (CRBR)—is a Liquid Metal Fast Breeder Reactor. The CRBR has the job of demonstrating that an LMFBR can be operated safely and reliably on a utility system. However, the CRBR is not the first LMFBR we have built. It is one of an orderly series of research, development and demonstration projects that started more than 25 years ago. We have had a small experimental breeder called EBR–II operating in Idaho for 13 years producing electricity and recycling the plutonium fuel it produces. We are building another LMFBR at Hanford, Washington, called the "Fast Flux Test Facility". It will test fuel and component parts for the Clinch River Plant and for future advanced reactor concepts. After the Clinch River Plant has operated for a few years, we may consider using it to test more advanced fuels and components, and we will probably build one more LMFBR after the Clinch River Plant. This will also be partially supported by private industry and will probably provide the final information that will be needed before utilities make the decision about building commercial breeders.



DEVELOPMENT OF THE LMFBR SPANS SEVERAL DECADES

CONGRESSMAN. I have heard this will all cost many billions of dollars.

SCIENTIST. Yes, that is true. The entire breeder program will cost more than 10 billion dollars from its inception in the mid-1990's to its completion in the early 21st century. It's important to keep in mind that that's a small portion of our energy research and development program during that time, and it may be less than we will spend on fusion or other energy research and development programs.



ENERGY RESEARCH IS EXPENSIVE–THE BREEDER WILL ONLY BE A SMALL PORTION

CONGRESSMAN. What about solar and geothermal energy, and nuclear fusion?

SCIENTIST. We are supporting all of them, too, with agressive programs. We hope to learn about these technologies and develop them in less time than we have taken for the breeder program. The urgency of our energy problem requires that we do them all at once, each in its own time slot and with its own approach. However, we believe that even if the potential for these energy sources is fully realized, we will still need nuclear power, including the breeder reactor.

CONGRESSMAN. But, you do think that we should support them all, the breeder, solar and geothermal energy, and the fusion program?

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Scientist. Yes, a lot of basic research and development will be needed on all these technologies. There are no simple solutions to the complex problems they represent. The future stability of our Nation depends on our providing responsible leadership both in government and in industry in support of all of these programs.

Congressman. Are more studies on the potentials and limitations of breeder reactors needed?

Scientist. It will surely be appropriate to reassess the breeder program at specific intervals or as new information becomes available on the LMFBR and its advantages or disadvantages relative to other energy sources. However, at this time we believe there has been ample studying of the problem, and it is now time to move on with the job and develop hard information and plant experience.

WE MUST WORK TOGETHER FOR A BALANCED ENERGY PROGRAM

SECTION II

BACKGROUND

A. PURPOSE OF THE REVIEW

On March 19, 1975, Senator John Pastore, Chairman of the Joint Committee on Atomic Energy (JCAE) established a Subcommittee under the chairmanship of Representative Mike McCormack to review the National Breeder Reactor Program and related activities of the Energy Research and Development Administration (ERDA). The purpose of this review was to examine the various concerns that have been expressed and questions that have been raised within the Congress and outside by members of the public with respect to several fundamental issues such as the need and timing for the Program, the cost and potential benefits to be realized from it, and the attendant risks associated with ultimate widespread commercial use of this type of energy production and conversion technology. This review was undertaken with full recognition that the LMFBR Program had been singled out by the Executive Branch as one of the Nation's highest priority energy research and development programs.

B. ACTIVITIES OF THE SUBCOMMITTEE

The Subcommittee's activities encompassed four major areas. These were:

1. Transmittal of a question sent to 90 organizations and individuals.
2. Public briefings.
3. Hearings.
4. Visit to European breeder reactor installations and discussion with European nuclear policymakers.

1. QUESTIONNAIRE

As a first step toward obtaining information and views from all sectors, Subcommittee Chairman McCormack dispatched a letter on April 11, 1975, to 90 agencies of government, representatives of industry, public groups, and others. The letter included 17 questions on issues such as the Nation's need for energy, the electrical component thereof, the alternative fuels and available resources, and the merits or demerits of a commitment to the development of the breeder reactor option as a partial solution to the projected electrical energy need. A listing of these questions is provided below.

ISSUES TO BE ADDRESSED—JCAE AD HOC SUBCOMMITTEE REVIEW OF LMFBR PROGRAM

APRIL 11, 1975.

Energy Trends

1. What will be the total U.S. energy demand in 1985, 2000, and 2020? What will be the corresponding percentage growth rates in energy demand? How much do you expect that conservation of energy will reduce the energy growth rates?

2. What are the limits of energy conservation as an alternative to expanding energy facilities, and what would be the economic and other consequences of such conservation measures?

3. Of the total energy growth, what will be the electrical energy component in 1985, 2000, and 2020? What percentage growth rate do you expect for electrical energy? What are the implications for the long-term of the recent significant reduction in electrical energy growth rates?

Energy Sources for Meeting Projected Demands

4. How will the future energy and electrical energy demands for the United States be satisfied, i.e., what will be the mix of energy sources in 1985, 2000, and 2020?

5. What will be the major shifts in energy sources in the future in comparison with our present primary fuel supplies?

6. What are the principal limitations for each of the various potential future fuel supplies for conversion into electricity?

7. How much should the United States rely on energy resources imported from abroad for meeting its domestic needs in the future?

Role of Nuclear Power

8. With respect to nuclear power, what is the most realistic forecast for use of nuclear power in the future, and what are the likely nuclear generating capacities in 1985, 2000, and 2020?

9. What do you anticipate the mix of reactor types will be in 1985. 2000, and 2020 to provide the nuclear component? This should include consideration of the light water reactors (LWR), high temperature gas reactors (HTGR), the liquid metal fast breeder reactor (LMFBR). and other advanced converter and breeder reactors.

Role of Breeder

10. What is the best estimate of the Nation's uranium and thorium resource base? What other major uncertainties are there concerning nuclear fuel supply (e.g., fuel costs, enrichment capacity, etc.)?

11. Considering the electrical energy projections, the status of LWR and HTGR technology, the potential role of non-nuclear energy sources, the uranium resource availability and other factors, is there a need for the breeder reactor, and if so, when?

Role of LMFBR

12. If a breeder reactor is considered to be needed, should this country continue to put its major effort on the LMFBR? What level of effort should be devoted to alternate reactor concepts?

13. Are the overall LMFBR program objectives, content and approach correct? What steps can be taken to minimize the costs of the program, and improve performance with respect to program schedules? What further steps should be taken to increase industrial involvement in the program?

14. Should the United States proceed with construction of the Clinch River Demonstration plant at this time? Would there be merit to delaying this plant until the Fast Flux Test Facility (FFTF) is completed?

15. What will be the total R. & D. costs for the LMFBR, and how will they be recovered? What is the predicted capital cost of commercial plants and what methods are available to provide that capital?

What are the expected fuel cycle costs? Will the LMFBR be economically viable?

LMFBR Safety/Environmental/Safeguards Issues

16. What are the major safety, environmental, and safeguards problems with respect to the LMFBR? Can these problems be satisfactorily resolved prior to the anticipated large scale commercial use of the LMFBR?

17. What actions are required to assure the safe handling and utilization of plutonium? What are the hazards of plutonium, as compared to other potentially dangerous substances used in our society?

A copy of Chairman McCormack's letter and the address list is included as Appendix 1 to this report. Responses were received from many of the groups and provided an initial base of information for the Subcommittee's identification and consideration of the major issues. The questions sent and the responses received have been compiled in a JCAE preprint and copies are available on request from the JCAE.[1]

2. Public Briefings

In order to provide the members of the Subcommittee with updated background material on nuclear power, the nuclear fuel cycle and the breeder program in particular, three public briefing sessions, before the Subcommittee were held at the end of April and beginning of May, 1975. The topics included in these briefings along with the names of those making the presentations are shown in the table below.

BRIEFINGS TO JCAE AD HOC SUBCOMMITTEE REVIEWING THE BREEDER

Date	Subject	Speaker
Apr. 29, 1975	Historical development of the nuclear power program.	Dr. Gerald Tape, former Commissioner of AEC.
Do	The nuclear fuel cycle	Mr. Ed Johnson, president, E. R. Johnson Associates.
May 1, 1975	Reactor types and characteristics	Dr. Lynn Draper, associate, professor and director, nuclear reactor laboratory, University of Texas.
Do	Enrichment process	Mr. George Quinn, former AEC assistant general manager for production and management of nuclear materials.
May 6, 1975	Status of civilian nuclear power program.	Mr. Bill Lee, senior vice president, Duke Power Co.
Do	Role of utilities in CRBR	Mr. Wallace Behnke, executive vice president, Commonwealth Edison.

Summaries of these briefing sessions were inserted in the Congressional Record and a compilation of these inserts is provided in Appendix 2 to this report.

3. Hearings

A series of seven public hearings was held by the Subcommittee during which testimony was received on the same general areas as addressed in the question set. The specific topics and the witnesses testifying before the Subcommittee are listed in the table below:

Session 1: ENERGY TRENDS—June 10, 1975

Mr. ALAN McGOWAN, *President*, Scientists' Institute for Public Information
Dr. JOHN HOLDREN, *Assistant Professor*, Energy and Resources Program, University of California, Berkeley

[1] "Issues for Consideration—Review of National Breeder Reactor Program," Joint Committee Print, August 1975.

Dr. BRUCE NETSCHERT, *Vice President*, National Economics Research Associates, Inc.
Mr. ROGER LEGASSIE, *Assistant Administrator for Planning and Analysis*, EDRA

Session 2: ALTERNATE ENERGY SOURCES—June 11, 1975

Dr. ALLEN HAMMOND, *Editor*, SCIENCE MAGAZINE, American Association for the Advancement of Science
Mr. MARC MESSING, *Staff Member*, Environmental Policy Center
Dr. JOHN TEEM, *Assistant Administrator for Solar, Geothermal and Advanced Energy Systems*, ERDA
Dr. JOSPEH OXLEY, *Section Manager, Fuel and Combustion Systems*, Battelle Memorial Institute

Session 3: SAFETY AND ENVIRONMENTAL ISSUES—June 17, 1975

Dr. WARREN DONNELLY, *Senior Specialist on Energy*, Library of Congress
Dr. DAVID ROSE, *Professor of Nuclear Engineering*, MIT
Dr. CHET RICHMOND, *Associate Director for Biomedical & Environmental Sciences*, Holifield National Laboratory
Dr. BERNARD COHEN, *Professor of Nuclear Physics*, University of Pittsburgh

Session 4: SAFEGUARDS—June 18, 1975

Dr. TED TAYLOR, *Chairman of the Board*, International Research and Technology Corporation
Dr. ORVAL JONES, *Director of Nuclear Security Systems*, Sandia Laboratories
Major General EDWARD GILLER (USAF Retired), *Deputy Assistant Administrator for National Security*, ERDA

Session 5: ROLE OF CONVERTER AND BREEDER REACTORS—June 24, 1975

Dr. HANS BETHE, *Professor of Physics*, Cornell Univ.
Mr. JOHN SIMPSON, *Director–Officer*, Westinghouse Electric Corporation
Dr. DEAN ABRAHAMSON, *Professor of Public Affairs*, University of Minnesota
Mr. LEONARD KOCH, *Manager of Nuclear Projects*, Illinois Power Company

Session 6: COST-BENEFIT ANALYSIS—July 10, 1975

Dr. CHAUNCEY STARR*, *President*, Electric Power Research Institute
Dr. THOMAS STAUFFER, *Lecturer*, Department of Economics, Harvard Univ.
Dr. THOMAS COCHRAN, *Staff Scientist*, Natural Resources Defense Council
Mr. SAUL STRAUCH, *Staff Member*, Reactor Research and Development Division, ERDA

Session 7; POSITION OF ERDA—July 17, 1975

Dr. ROBERT SEAMANS, *Administrator*, ERDA

The general format for the hearings was to have a presentation of prepared testimony by the witness, followed by a question and answer period. A summary of each hearing, including the question and answer period, was prepared and inserted into the Congressional Record. A compilation of these summaries is also provided in Appendix 2.

In addition to the scheduled hearings listed above, the Subcommittee on May 7, received testimony from Mr. Russell Train, Administrator of the Environmental Protection Agency, and from Mr. John Hill, Deputy Administrator of the Federal Energy Administration. These testimonies were presented for the purpose of clarifying certain Executive Branch views relative to the breeder. The principal concern of the Subcommittee was the interpretation being given by some to EPA's comments on the Proposed Final Environmental Statement (PFES) for the LMFBR. In the hearing and in subsequent correspondence with the subcommittee, Mr. Train made it clear that EPA supported

*Dr. Starr testified on an overall energy strategy for the Nation and not on Cost/Benefit Analysis.

development of the breeder and continuation of the Clinch River demonstration project.

4. On-Site Review of Foreign Reactor Programs

During the July congressional recess, the Subcommittee visited Scotland, England, France, and Germany for the purpose of studying the goals, approach, performance, status, and future plans of the LMFBR programs in these countries. The Subcommittee sought to determine the similarities and differences between Western European and U.S. breeder development programs and to ascertain what, if any, changes to the U.S. program might be appropriate in light of foreign experience. Members participating in this review were Representative McCormack, Subcommittee Chairman, and Representatives Anderson, Horton, and Hinshaw. Those attending were afforded a close-up examination of the British prototype fast breeder reactor and the French Phenix fast breeder, both of which were operating at the time. The Subcommittee found that nearly all countries in Western Europe are involved in the development of the LMFBR, either through cooperative agreements or through their own programs. They are unanimous in their belief that the LMFBR is necessary to meet their future energy demands. A more detailed set of impressions formed by the Subcommittee during the trip has been prepared and is provided as Appendix 3 to this report.

Section III

ISSUES RELEVANT TO THE BREEDER PROGRAM

A. ENERGY TRENDS

Conclusions

After having carefully reviewed the information submitted to it on the subject of energy trends, the Subcommittee concludes that:

1. Although forecasting national energy consumption is an imprecise science, and at present only marginally useful in forecasting energy consumption patterns and production levels for various technologies, there are trends, which taken along with a realistic appraisal of what can be accomplished to alter them within a given time frame, provide a valuable tool for understanding energy requirements for the future.

2. Energy growth rates, both total and electrical, may in the near term be lower than has been seen in the past. However, substantial forces do exist which will prevent these growth rates from declining precipitously from historical levels, and for sustained periods during the balance of this century. These realities are fundamental to energy planning.

3. A minimal compounded energy growth rate of slightly less than 3.0 percent per year represents a reasonable "best guess" for energy planning purposes. Adjustments in this estimate may be necessary as further data are accumulated.

4. A minimal compounded electrical growth rate of about 5.5 percent per year should be used for planning purposes. This would result in an electrical generating capacity of 550 gigawatts in 1985 and 1230 gigawatts in the year 2000 (average capacity 65 percent). Recognizing again that these projections are imprecise, they nevertheless provide a basis by which energy policy can be established. (The present U.S. installed capacity is 430 gigawatts.)

Introduction

In recognition of the dramatic changes in the Nation's energy usage and consumption patterns over the last two years, the Subcommittee felt that a review of the need and timing of the LMFBR program must begin with an examination of the changing energy consumption and production patterns in the United States and the role that nuclear power, including the breeder reactor, may be expected to play in the Nation's energy future. The Subcommittee in its hearings and investigations therefore sought information on the trends in

energy consumption, the mix of energy resources available to meet those needs, the growth in electric power consumption and the role of nuclear power in general in meeting energy demands.

Questions and Responses

In the letter sent to 90 organizations and individuals as discussed in Section II.B., the Subcommittee included the following questions:

1. What will be the total U.S. energy demand in 1985, 2000, and 2020? What will be the corresponding percentage growth rates in energy demand? How much do you expect that conservation of energy will reduce the energy growth rates?
2. What are the limits of energy conservation as an alternative to expanding energy facilities, and what would be the economic and other consequences of such conservation measures?
3. Of the total energy growth, what will be the electrical energy component in 1985, 2000, and 2020? What percentage growth rate do you expect for electrical energy? What are the implications for the long-term of the recent significant reduction in electrical energy growth rates?

The responses to these questions, and the conclusions of many studies on this subject which the Subcommittee carefully reviewed, were diverse. Projections of total energy growth to the year 2000 (hardly anyone was willing to extend to 2020) ranged from the high cases, based on an assumed continuation of the rapid, exponential growth rates of the past two decades, to low estimates based on the imposition of substantial and controversial conservation measures.

This diversity reflects the fact that widely differing scenarios of energy growth over the next 25 years can be constructed using only a few essential determining factors. Those chosen by the various respondents may have been selected more as a consequence of individual bias rather than conclusions drawn from existing energy data.

In this regard, it is interesting to note that both the critics and the advocates of the fission reactor program were generally found to agree that energy demand will continue to increase for the foreseeable future. The degree to which this happens is the point of departure. Critics believe that it is possible to either mandate or produce by governmental controls and/or stringent conservation programs, very low growth rates and thereby obtain extra time for developing what critics consider to be the "more benign" sources (which they also consider to be more sociologically acceptable), thus bypassing the need for the LMFBR.

Supporters on the other hand contend that such conservation programs produce unacceptable side effects on the economy and employment and that when the government actually attempts to put them in place, significant political forces will be brought to bear which could make their implementation difficult. They cite the events of the last year in attempting to write an energy policy as their example.

If one might fault the low energy growth projections as unduly relying on the success of stringent conservation measures, one also may observe that the high growth cases are also somewhat unrealistic in that they are based on historical growth trends with little or no allowance built into them which would reflect current changes in energy prices, trends, shortages, and consumption patterns.

The subject of energy conservation figured importantly in much of the information presented to the Subcommittee, and is worthy of further examination in this report. While agreeing that conservation measures would certainly impact total energy growth in the next 25 years, many respondents felt it difficult to predict the extent of that impact. Those that did generally had conservation impact estimates that ranged from 5 percent to 25 percent in the 1985–2000 time period, and these estimates have been included in the Subcommittee's evaluations.

However, it is important to note that there were consistent opinions expressed among some respondents that conservation measures, or more accurately stated, reductions in energy consumption, as have been experienced during the last year and a half, are not true conservation measures and if repeated could mean substantial reductions in economic activity in this country, loss of jobs and job security, etc. Several respondents felt that there could be (and has been) a one time conservation effect and that for a short time consumption would drop, but that as people accommodated themselves to their lower level of consumption, historical forces would again be set in motion and growth in energy consumption would resume. This would be at a lower rate, to be sure, but yet at a rate that was likely to be somewhat greater than the rate of population growth.

In consideration of the wide range of views on future energy demand as represented by estimates of energy conservation, the Subcommittee was unable to elicit agreement, or even a consensus, concerning which energy usage options are most acceptable on an economic, social, or technological basis. Nevertheless, the respondents' diversity did give the Subcommittee an opportunity to seriously consider all the options, and out of that consideration came basic conclusions as discussed below on energy growth and the role that nuclear power in general, and particularly the breeder, can play in the Nation's energy future.

THE ENERGY GAP

In discussing the energy picture for the remainder of the century, witnesses presented the Subcommittee with a consensus on two basic and very general premises. First, the historical growth rates of the past decade or so, ranging up toward 3.6 percent a year, will most, likely not continue. The drastic rise in price of all energy forms combined with efforts to use energy more efficiently, will inevitably slow that growth rate. Second, because of the structure of our society, energy consumption will continue to grow, although at somewhat reduced rates, and will probably continue to grow faster than the population. This will be particularly pronounced during the next decade, as the age groups born in the baby-boom years of the 1950's and early 1960's come to maturity and enter the labor force.

It was also generally suggested that restriction of energy consumption much below two percent a year would probably require substantial governmental constraints and negative economic pressures that would be socially and politically unacceptable to the American people.

Based on information presented to the Subcommittee in the hearings and documentation, the range of growth patterns which can be reasonably forecast is shown in figure 1. At historical growth rates of 3.6 percent per year, total energy consumption in 2000 would be the equivalent of 82 million barrels of oil per day (Mb/d). If maximum proposed conservation efforts are employed, resulting in a growth rate of about 2 percent per year, the consumption will be the equivalent of 50 Mb/d in 2000. Within these two limits fall the projections of most of the studies available to the Subcommittee, including but not limited to the "No New Initiatives" scenario from the ERDA June 30 study, "Creating Energy Choices for the Future" and scenarios from the Ford Foundation's Energy Policy Project (EPP).

[Figure 1 follows:]

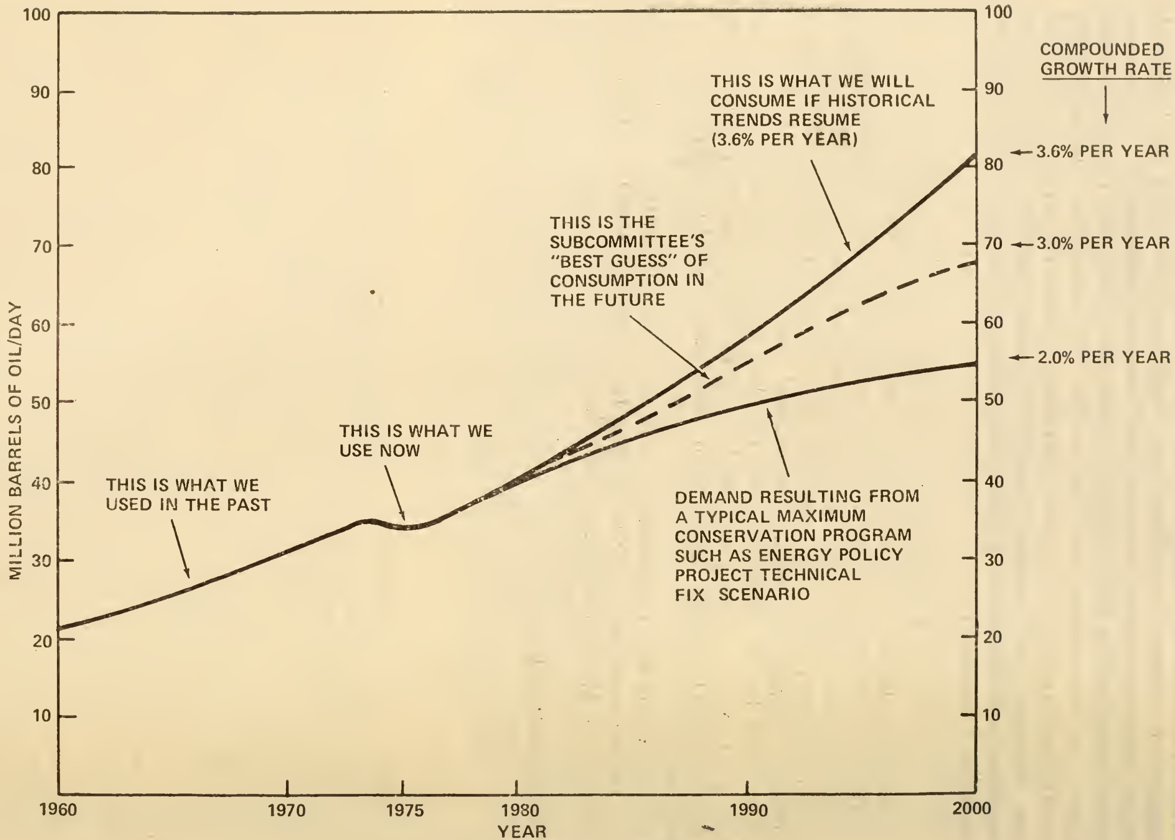

Figure 1 — TOTAL ENERGY DEMAND

The dotted line in figure 1 is what the Subcommittee considers to be a reasonable representation of energy demand in the next quarter century. It shows the energy growth rate recovering to a level of about 3 percent per year, somewhat below historical levels but yet held at this level by substantial demands for energy to fuel economic recovery, build a new energy base and fill in while more energy efficient end-use items, such as high mileage automobiles, are developed.

With the arrival of these more efficient end-use technologies, growth would slowly decline to around 2.5 percent per year. This changeover would be slow and one might expect that it would occur during the time frame between 1985 and 2000, depending on the timing and feasibility of many technological improvements. For the entire 25 year period this would result in a growth rate of energy consumption equivalent to about 2.8% per year.

The curve that the Subcommittee presents represents a logical extension into the future that is considerate of the need for a sound economy, reasonable levels of employment and an industrial base that will allow us to prepare for the conversion to new technologies for producing and consuming energy. It may well turn out to be slightly higher or lower, depending on a great many factors which cannot in any sense be quantified now. In the Subcommittee's view this is not a large uncertainty and will not materially affect the conclusions of this report even if these projections are high by as much as 5–10 percent.

Comparing these demand curves with our current production capabilities, as is shown in figure 2, graphically illustrates the extent of the energy gap that this country will face.

[Figure 2 follows:]

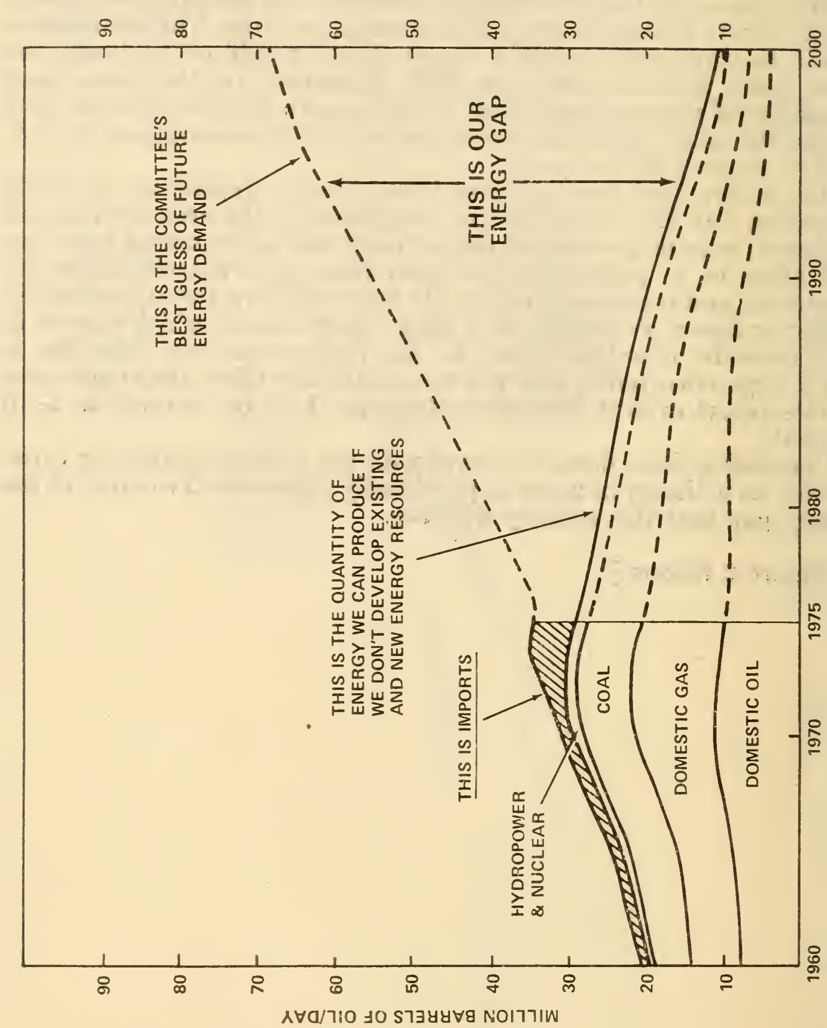

Figure 2 — THE ENERGY GAP

To illustrate the extent of the marketplace in which energy production technologies will compete, the Subcommittee shows in figure 2 approximately what will happen to our domestic energy production capability for the next quarter of a century. Oil and gas fields dry up, coal mines are depleted, nuclear plants age and need to be replaced, etc. As the production capacity currently in place deteriorates, the demand keeps rising. The difference between what our capacity currently in place now will produce then and what will be demanded then by energy consumers is what the Subcommittee calls the "energy gap." The energy gap represents the investment that this country will have to make by that time in new energy production equipment. As is shown in the figure, the energy gap in the year 2000 amounts to about 55 million barrels of oil per day equivalent, about double what we are capable of producing in this country today. And from the figure one should also note that of the total production in place in 2000, whatever the type, only a small fraction will be from resources that are currently producing.

This then, illustrates the magnitude of investments needed in energy production for the next 25 years. We must not only replace essentially every known and producing energy source that currently exists but we must find a new one of comparable capacity and develop it as well. And since it is commonly agreed that we have found and used most of the easily-obtained oil and clean gas and coal in this country, the need to replace and double our existing capacity by using marginal resources will clearly put tremendous burdens on our land, water and air. There can be no doubt that the clean and easily obtained energy sources are going to have a substantial advantage in this marketplace.

Conclusions

After having carefully reviewed the information submitted to it on the subject of energy trends, the Subcommittee concludes that:

1. Although forecasting national energy consumption is an imprecise science, and at present only marginally useful in forecasting energy consumption patterns and production levels for various technologies, there are trends, which, taken along with a realistic appraisal of what can be accomplished to alter them within a given time frame, provide a valuable tool for understanding energy requirements for the future.

2. Energy growth rates, both total and electrical, may in the near term be lower than has been seen in the past. However, substantial forces do exist which will prevent these growth rates from declining precipitously from historical levels, and for sustained periods during the balance of this century. These realities are fundamental to energy planning.

3. A minimal compounded energy growth rate of slightly less than 3.0% per year represents a reasonable "best guess" for energy planning purposes. Adjustments in this estimate may be necessary as further data are accumulated.

4. A minimal compounded electrical growth rate of about 5.5 percent per year should be used for planning purposes. This would result in an electrical generating capacity of 550 gigawatts in 1985 and 1230 gigawatts in the year 2000 (average capacity 65%). Recognizing again that these projections are imprecise, they nevertheless provide a basis by which energy policy can be established.

B. THE ENERGY GAP—HOW TO FILL IT

Conclusions

The material reviewed by the Subcommittee indicates that (1) the Nation will be forced to substantially decrease its dependence on oil and gas because these fuel resources will continue to dwindle dramatically even when reinforced by offshore and synthetic programs; (2) electrical energy will as a result be substituted for direct use of oil and gas wherever practicable; and (3) coal and nuclear power will be the major sources of energy used to generate the increasing amounts of electricity required for the balance of the century.

Current Energy Use Patterns

In order to find ways in which to fill the energy gap, and to determine the role of nuclear power in that process, the Subcommittee posed the following additional questions in the letter referred to earlier:

Energy Sources for Meeting Projected Demands

4. How will the future energy and electrical energy demands for the United States be satisfied, i.e., what will be the mix of energy sources in 1985, 2000, and 2020?

5. What will be the major shifts in energy sources in the future in comparison with our present primary fuel supplies?

6. What are the principal limitations for each of the various potential future fuel supplies for conversion into electricity?

7. How much should the United States rely on energy resources imported from abroad for meeting its domestic needs in the future?

Role of Nuclear Power

8. With respect to nuclear power, what is the most realistic forecast for use of nuclear power in the future, and what are the likely nuclear generating capacities in 1985, 2000, and 2020?

9. What do you anticipate the mix of reactor types will be in 1985, 2000, and 2020 to provide the nuclear component? This should include consideration of the light water reactors (LWR), high temperature gas reactors (HTGR), the liquid metal fast breeder reactor (LMFBR), and other advanced converter and breeder reactors.

The Subcommittee indicates in figure 3 what it considers to be a plausible way that the energy gap will be filled. It should be emphasized that in analyzing responses from witnesses and respondents, the Subcommittee was presented with a wide variety of methods for filling this energy gap. The Subcommittee did not, for many reasons, wish to undertake an independent assessment of the viability of various technologies during the next 25 year period. In discussing how it thinks the energy gap might be filled, the Subcommittee would like to emphasize some general points which have served as useful guidelines in attempting to assess the role that various energy sources might be expected to fill in providing the energy needed to fill this energy gap.

[Figure 3 follows:]

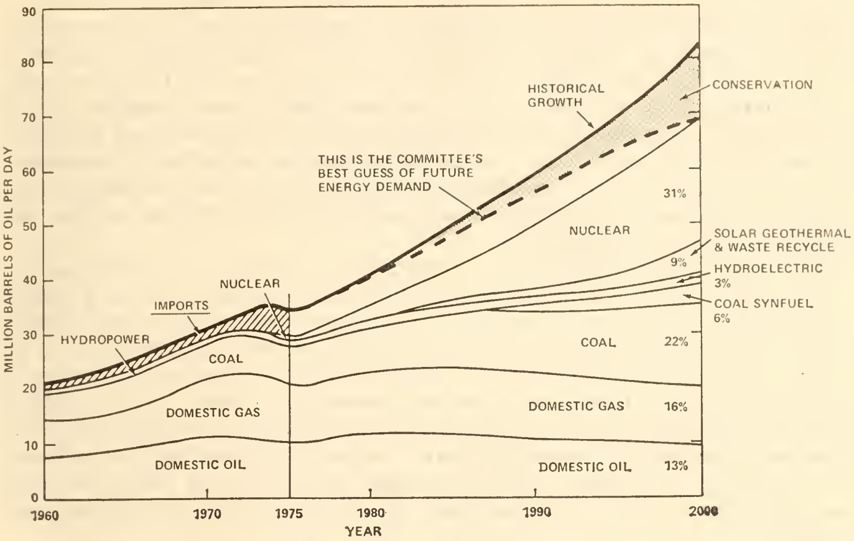

Figure 3 – FILLING THE ENERGY GAP

Conservation is a powerful and effective tool for relieving pressure on our energy resources. In the committee's best guess for future energy demand (top dotted curve in figure 3) the Subcommittee has included conservation effects which hold growth rates between 15 and 20 percent below historical levels until about 1985–1990, and then reaching almost 30 percent below historical levels. These conservation efforts will result in a reduction in demand of about 15 Mb/d equivalent, a little less than half of our current domestic production capacity.

The Subcommittee does not feel that it is prudent or responsible to make planning decisions with conservation levels greater than these. Evidence presented to the Subcommittee indicated that the correlation between energy, GNP and employment remains strong, despite differences between the U.S. and other nations. While representing a more efficient utilization of energy generally, conservation, if carried too far, negatively impacts the economy and employment. The Subcommittee considers the need for a sound economy and a healthy job market to be critical factors in the energy planning and therefore does not wish to either over-emphasize or under-emphasize the conservation potential. The level chosen here represents what it considers to be plausible and responsible.

The second important constraint built into figure 3 is the essential constant production of oil and gas for the next 25 years. This could well be slightly optimistic considering the entire weight of evidence presented to the Subcommittee. ERDA shows that domestic production from existing wells will decline dramatically in the near future and to maintain constant production, advanced recovery

methods will have to be employed extensively. Other studies have shown roughly the same trend and the Subcommittee feels that within 10–20 percent, production will likely remain essentially as it now is for the next 25 years. However, it must be emphasized that the long-term maintenance of this production level will not be possible. All of the evidence presented to the Subcommittee indicates that in 2000, oil and gas reserves will be dangerously close to depletion if we maintain consumption at these levels. And if anything, the Subcommittee would be more comfortable using slightly lower estimates for the near future for oil and gas.

The third constraint that is evident in figure 3 is that alternative and exotic technclogies are not going to be able to provide meaningful quantities of energy until sometime after about 1985. They include solar, geothermal, waste recycle, etc. During the last 15 years of the century, however, the Subcommittee expects that they will rapidly improve their contribution, reaching about 7.5–8.5 Mb/d equivalent by 2000, about a quarter of our current total energy production capability. This will require a major effort and work to achieve this level of production needs to begin soon. It is in this area that we are going to have to take much of the load off of our oil and gas sources.

Hydroelectric capabilities are limited and although there are some possibilities for expansion, environmental difficulties are going to be a major deterrent to major expansions in this area.

This leaves coal and nuclear with a substantial gap yet to fill. The coal levels in figure 3 show a doubling of coal prodution over current levels by about 1985 or 1987 and a tripling by the year 2000.

These levels are consistent with information presented to the Subcommittee during this review and with a reasonable balancing of environmental, economic, and employment considerations should be possible of achievement.

This leaves a substantial role for nuclear power as a major component of our energy production network. From the figure it is clear that it is the major technology which is capable of making a significant dent in imports and the only one capable of removing our dependence on imports by the year 2000. The equivalent number of 1000 MWe plants shown in figure 3 is about 650 in the year 2000. More discussion of the role of coal and nuclear is contained in the following section on electric power.

Electric Power's Future

To obtain an estimate of electrical demand growth during the next 25 years, the Subcommittee analyzed responses to questions involving electrical growth trends in the same way as total energy. The responses, in a similar fashion to total energy growth predictions, ranged from very low to quite high, approaching historical levels, and reflected in many cases the proclivities of the respondents more than any well substantiated basis from which to make a prediction. Nevertheless, these projections, and the perspectives used to obtain these projections, were quite useful to the Subcommittee since they presented essentially all of the different considerations and options that the Subcommittee should address in its review.

These projections showed that if the estimates of total energy consumption in the United States are diverse and uncertain, the uncertainties in projecting electric power consumption, according to those testifying before the Subcommittee, are even greater. This is due in part to the strong likelihood that, according to several witnesses, electric power consumption will grow faster than the total energy growth rate, but the extent to which this will occur is difficult to determine. A fundamental question in this regard is the success that will be achieved in efforts to convert many end uses of energy from petroleum fuels to electric power (produced from coal or uranium) in order to reduce the heavy and economically damaging dependence on imported oil and the even more serious problem of depleting a major resource of this Nation.

Another factor that will affect the rate of electric power growth is the rate of adoption of solar heating and cooling in buildings. Estimates vary widely on the extent to which the technology will be applied. The contribution to be expected from solar heating and cooling, as well as from the more difficult technology of direct solar generation of electricity, is discussed in Section III.C.

The projections of electric growth received by the Subcommittee varied by a factor of two, from approximately the historical growth rate of 7.8 percent per year to a very low annual figure of about 4 percent. Because of the expected moves to convert to electrical end use in industrial and commercial sectors, and perhaps in transportation, the Subcommittee feels it is prudent public policy to expect that electric consumption will grow at an annual rate at least as large as 5.5 percent per year for the rest of the century. That rate seems to be close to a lower limit; it could well be higher, recognizing that the "evidence" of lowered growth rate over the last two years has been accumulated during a period of economic recession, and high unemployment, when electricity growth rates are normally lower. Thus, the reduced demand may not be as closely correlated with price-elasticity and willingness of consumers to conserve as some low-growth advocates suggest. Furthermore, basing electrical consumption patterns on the experience of the last 2 years is not, in the Subcommittee's opinion, a prudent policy.

Whether energy demand is high or low, most persons presenting information to the Subcommittee agreed that if the full advantage of electric power in reducing the Nation's dependence on foreign energy sources is to be realized, the anticipated growth rates must not be met by means of petroleum-fired generating plants. While there was some disagreement on how these demands should be met, those witnesses with responsibilities for providing the Nation with electricity generally did agree that the major sources of domestic fuel for electric power generation must be coal and nuclear power.

This is graphically illustrated in figure 4 where the Subcommittee shows our electrical consumption patterns for the past 15 years as well as defining the extent of the Electrical Generating Capacity Gap for the remainder of this century.

[Figure 4 follows:]

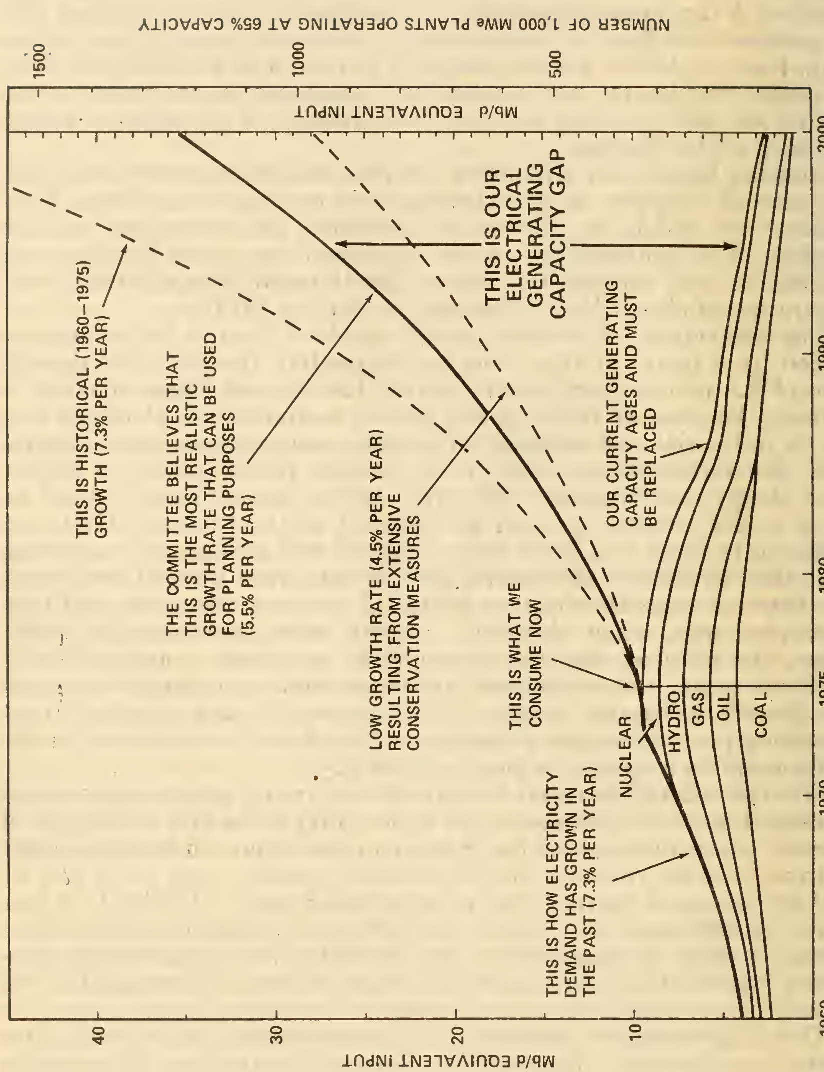

Figure 4 – THE ELECTRICAL GENERATING CAPACITY GAP

As was explained in Figure 2, the current production capacity will age and need replacement at a substantial level during the coming years. And because of the relatively large electrical growth rate, compared with total energy, the electrical generating capacity gap grows very rapidly. By the year 2000, we will have to have built about 1,100 large electrical generating stations of the 1,000 MWe class to meet expected demand. If we triple our coal production by then, about 450-500 of them will be coal fired and 600-650 will be nuclear.

The Subcommittee would like to emphasize here that there are still substantial uncertainties in the environmental and technical area which directly bear on which of these technologies will have a competitive advantage. Constraints imposed by the Clean Air Act and possible additional constraints from strip mine legislation weigh heavily on the future of coal because of the large cost penalties associated with fuel and scrubber equipment in the consumer's bill. Even though there are substantial uncertainties in the back end of the fuel cycle for the nuclear industry, they do not represent a large increase in cost of electricity produced in the plant because of the small cost associated with nuclear fuel.

The Subcommittee therefore believes that the figures quoted above; for coal and nuclear in 2000 represent minimal figures for nuclear and they could very well range upwards by 100-200 plants. These levels will go even higher if electrical growth rates are found to be in excess of the 5.5 percent shown here.

Conclusions

In reviewing the predictions of the high and low growth cases and in recalling events of recent months as the Congress has attempted to forge a national energy policy, the Subcommittee is led to the inescapable conclusion that both historical trends and extreme societal constraints on energy consumption are highly unlikely scenarios for either constructing a national energy policy or even predicting possible patterns of national energy consumption. For the high growth cases, increased energy prices are naturally going to introduce lower growth rates than have been observed historically. On the other hand, coming to general agreement on which energy conservation programs should be implemented is likely to continue to be a difficult societal and political task.

Therefore, recognizing the need to minimize the effects of the extremes and to produce what it considers to be a reasonable estimate of what energy growth patterns will look like in the future, the Subcommittee concludes that planning for energy demand should focus more on the middle range of the projections made in the responses received as shown in figure 1. Thus, the Subcommittee feels that total energy growth rate of 2.5-3 percent per year is reasonable. It is likely that for the next few years growth will be in the 3 percent range, and slowly decline to 2.5 percent by 2000.

Because of the general agreement that oil and gas supplies are limited and that the Congress will put in place policies to manage this now scarce resource, the Subcommittee concludes that there will be a shift to using electricity, therefore, electrical growth rates will be substantially larger than total energy growth. This separation of

electrical growth rates from the total energy growth is critical to understanding the role that nuclear energy might play.

The material reviewed by the Subcommittee indicates that (1) the Nation will be forced to substantially decrease its dependence on oil and gas because these fuel resources will continue to dwindle dramatically even when reinforced by off-shore and synthetic programs; (2) electrical energy will as a result be substituted for direct use of oil and gas wherever practicable; and (3) coal and nuclear power will be the major sources of energy used to generate the increasing amounts of electricity required for the balance of the century.

Recommendations

Because nuclear power must play a significant role in meeting electric demands in the very near future, the Subcommittee believes that every reasonable effort should be made now to ensure that nuclear power will be able to fulfill its potential contribution.

C. ALTERNATIVE ENERGY OPTIONS

Conclusions

Based on testimony from the ERDA and from a number of other experts, the Subcommittee concludes that energy production will be as shown in fig. 3 on page 39.

The Subcommittee strongly endorses the substantial increases in funding for alternative energy options, including solar and geothermal power, recently approved by the Congress. The Subcommittee accepts the ERDA projections for the rate of commercialization of alternative energy sources for meeting future energy needs. The Subcommittee notes, however, that even if these projected energy contributions from solar, geothermal and other alternative technologies were to be doubled our fundamental conclusions regarding the need for nuclear power would not change significantly. (Waste conversion is not included in this assumption as waste is a finite resource and cannot be arbitrarily doubled.)

As an adjunct to the Subcommittee's review of the breeder program, alternate energy sources were studied to determine their potential contributions in meeting our nation's future energy needs. As with the other issues examined, responses to the Subcommittee's questions were received from a wide range of government, industry and private groups and individuals. Oral testimony in open hearings was also received.

One fact was immediately obvious; everyone agreed that development of these alternate energy options was needed and should continue to be vigorously pursued. The energy resource which received the greatest attention was solar energy; other potential energy sources covered in less detail were geothermal, fusion, wind, ocean thermal gradients, and bio-mass conversion. Several of the options above, once developed, would provide inexhaustible sources of energy supply. As such, they are most attractive when considering our dwindling supplies of oil and natural gas. These alternate energy options also appear very attractive from safety and environmental considerations. The potential air-borne pollution or mining problems

from these energy sources appear much less than today's fuels such as coal; the long term waste disposal or diversion problems presently associated with nuclear power do not exist for these sources. Safety and environmental issues are present and must be addressed, but in general they are not the same magnitude as some of the current issues involved with nuclear and coal.

MID-RANGE ENERGY DEMAND PROJECTIONS: 1985 AND 2000

As discussed earlier, the mid-range energy demand projections for the years 1985 and the year 2000 are:

Year	Electricity Demand (barrels of oil equivalent)
1985	15, 800, 000, 000
2000	35, 300, 000, 000

Projections for electrical production by alternate energy sources which would help meet some of this demand were provided by many organizations. There was a considerable range of projection as can be seen in the table below.

Percent Contribution Toward Meeting Electrical Demand in Year 2000

Solar	Less than 1 percent to greater than 20 percent
Geothermal	1 percent to 20 percent
Fusion	0 percent to less than ½ percent.

The high estimates were made by those assuming that each of the various technical and economic problems were overcome. For example, Dr. John Teem, Assistant Director for Solar, Geothermal and Advanced Energy Systems, ERDA, in testimony to this Subcommittee characterized his projections as goals which could be reached "assuming that research, development and commercialization are successful." Those who are more pessimistic about alternative energy sources made projections on the low side, citing materials development problems and the need for component cost reductions (in some cases two to three orders of magnitude) before certain systems would become cost effective.

With respect to solar power, care must be taken to separate potential contributions from solar for home heating and cooling uses versus direct electrical output applications. Witnesses were quite united in their belief that solar energy would begin making significant contributions for heating and cooling, particularly in new construction. Some witnesses also advocated large scale retrofit of existing homes. For this application, however, the cost effectiveness was not clear. As pointed out in one of the hearings, the cost to retrofit a house for solar heating and cooling has been estimated to be between $10,000 and $15,000. Presently, 20 percent of our energy goes into heating and cooling of houses. There are roughly 70,000,000 houses in this country and if one assumes that as many as 10 percent of them undergo this retrofit, 10 percent of 20 percent, or 2 percent of our total energy needs could be supplied by solar energy. Actually, the 2 percent figure would be further reduced considering the fact that solar energy could not supply 100 percent of the heating and cooling requirement, and backup systems would be needed a portion of the time. This means that between $70 to $105 billion would have to be spent to have solar energy

supply 1½–2 percent of our energy needs. Resistance to such large investments on existing homes and buildings is one major reason that new construction is seen as the principal widespread application for this use of solar energy.

While there was agreement on the contributions to be made by solar energy for space heating and cooling, there were differences of opinion concerning the contribution solar energy would make toward electricity production. As pointed out in the Proposed Final Environmental Statement for the LMFBR Program, about $1.4 \times (10)^9$ megawatts (thermal) per year fall on the U.S. from the sun. "If converted at a 10 percent efficiency, solar energy could provide electricity at a rate greater than 100 times the rate of consumption expected for the year 2000." However, the cost of this conversion must be competitive with other resources. A favored location for solar application is in the Southwest United States. This is because of the high percentage of time the sun shines in this part of the country and due to the large land commitment needed for conceptual solar central power plants. It has been estimated that to produce the equivalent of a 1,000 MWe plant, a solar-energy conversion system would have to cover approximately 10 square miles of land for power produced by thermal conversion, 30 square miles for photovoltaic conversion and 500 square miles for power produced by the combustion of photo synthetic materials. ERDA, in the PFES, considers this use of land (for thermal conversion) to be reasonable, however, when compared to the land use required to produce the same power by strip mining of coal. On the other hand, the land use for photosynthetic means (i.e., growing of large amounts of trees or other substances to burn) does not seem as reasonable.

Another item with respect to the thermal conversion systems mentioned above is the research and development needed to develop better collector, heat transfer and storage systems. This research and development is being pursued by both government and industry.

Another point made to the Subcommittee was that backup heating and cooling systems would be needed even though solar heating and cooling were used in a house. The dependency on the backup system would increase as the application of solar energy was used in areas of decreasing average solar incidence per day (e.g., Arizona averages 24 watts/ft^2 while Wisconsin averages 12 watts/ft^2 of incident radiation). Further, utilities are required to provide the electricity needed for home and industry. Therefore, the degree of installed capacity of electrical production by means other than solar energy would not decrease by an amount equal to that supplied by solar energy since for prolonged periods of cloud cover, people and industries would turn to their backup systems. Utilities would have to have the installed capacity to meet such demands (savings on fuel costs would be realized but the high capital costs of installed generating capacity would still exist).

Photovoltaic conversion methods have been developed and witnesses before this Subcommittee indicated a wide use and application for such systems. It was also pointed out, however, that the current cost of electricity from these units is extremely high. Dr. Alan Hammond, American Association for the Advancement of Science, estimated that cost reduction by a factor of approximately 100 is needed before

photovoltaic conversion could be cost competitive. Dr. Teem of ERDA estimated a factor of 100 to 1000. Advocates believe, however, that such cost reductions are quite reasonable if mass production techniques were adopted and innovations similar to those shown by the electronics industry were used.

Electrical production from geothermal energy involves direct use of hot water or steam available at certain locations directly on the earth's surface, use of geopressurized formations in which gases are found under pressure with hot water and use of hot dry rock, which can be used to heat injected water. The first method is already in place and does not require any special research and development. As indicated in testimony by Dr. Teem, the second and third areas will require advanced technology development.

Estimates of potential electricity production from geothermal power vary greatly. The Hickel panel[1] provided low to high range estimates of from 5 to 20 percent of the Nation's electrical energy output by the year 2000. The Bureau of Mines estimates around 2 percent. There is no doubt about the great reservoir of heat located in the earth's surface—the problem is recovering it economically and with acceptable environmental impact. Potential environmental effects cited include: (1) surface and groundwater quality impairment as a result of fluid disposal, (2) air emissions, particularly hydrogen sulfide, (3) noise from drilling and steam venting during operation, (4) uncontrolled blowouts, (5) aesthetic impact, (6) land subsidence from fluid withdrawal, (7) seismic activity from fluid withdrawal or reinjection, and (8) land use.

In addition, Dr. Teem cited the lack of assurance of the feasibility of profitable production of electricity over the lifetime of a plant as a major hindrance to early development of geothermal power. Other items noted were lack of uniform legal definition of geothermal resources for tax and ownership purposes, capital requirements, possibility of subsidence, leasing difficulties and the long lead time between resource discovery and economic development. These were all areas that are or will be addressed in the geothermal program.

The Subcommittee did not devote a large amount of time to the review of the potential for fusion energy since the promise held by fusion is well known, as well as the magnitude of technical achievement required in this program. The projections for electrical production by the year 2000 are quite small and therefore, if developed, fusion would offer an alternate only after the turn of the century. Members of the Subcommittee expressed continued strong support for the fusion program.

Only limited discussions were held on other potential alternatives such as wind power, ocean thermal gradients, tidal power or energy from organic wastes. The contributions to the electrical supply from these potential energy sources were not projected to be very large because feasibility questions, technology advances or environmental problems exist for these sources. One example brought out in the hearings dealt with wind power. In order to supply 1 Mw of electricity from a windmill, it would be necessary to construct a structure about 300 ft. high (35 stories) with arms 100 feet in length. In order to

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[1] Hearings before Committee on Interior and Insular Affairs, U.S. Senate, Series No. 92–31, p. 185.

provide electricity equivalent to a 1,000 Mw(e) plant, one would need to build such windmills at intervals of every 200 feet for a length of 40 miles. In addition to the unreliability of the wind source, the environmental implications, the cost of construction and other problems such as interference with microwave transmissions or bird flights were noted as serious constraints.

One of the principal arguments against continuation of the breeder program raised by some critics is that the high cost of the breeder will draw funds away from these energy alternates so that they will not be developed in a timely fashion. NRDC, in their publication "Bypassing the Breeder," put it as follows:

> The most serious danger is that the LMFBR Program will proceed as now planned, consuming the $10 billion presently estimated and plenty more besides, cutting deeply into energy R. & D. funds, and holding back the development of the preferable non-fission technologies. Then, having spent enormous sums the country will find itself with a reactor which must eventually be used only because of the great public and private investments in it and our failure to have developed appropriate alternatives.

Another assertion, frequently made, is that the budget for the breeder is several times that for other options and equal funding should be provided for each resource.

In the review by this Subcommittee, however, these charges and claims do not appear valid considering the history of these programs, the current status of the programs and project development activities. As an example, the table below shows the funding levels for solar research for the past six years. As can be seen, significant increases in funding have occurred each year, indicating Congress' intent to fully support development of these energy alternatives. In fact, in several instances, Congress has provided more funds for these programs than requested by the Executive Branch.

Year:	*Funding (millions)*
1971	1. 2
1972	1. 7
1973	4. 0
1974	13. 0
1975	50. 0
1976	114. 7

Another point often overlooked pertains to the relative stage of development of the LMFBR, solar energy, geothermal power, etc. The LMFBR is at an advanced state of development and is in the demonstration plant phase. This is the high-cost intensive phase of the program and is expected to require funding at levels higher than technologies earlier in development. This same trend can be observed in the fusion program, for example. As this program reaches the plant construction stage, funding levels will necessarily have to be increased to meet the capital cost of the facilities.

That adequate funds have and are being supplied for alternate energy sources is also borne out by statements from ERDA officials involved in administering the Solar, Geothermal and Advanced Systems Development program. In hearings before this Subcommittee, Dr. Teem indicated that current funding levels were adequate for

their current programs and that he believed sufficient funds would be made available in the future for development of these important energy options.

From the written information provided and from the hearings on alternate energy options, the overall consensus from witnesses not involved with the LMFBR program was that all energy options should be developed, including the LMFBR. Several witnesses made the point that a commitment to commercialization of the LMFBR should not be made now.

As discussed in Section III.E, no such commitment is being made at this time.

In this section of the Subcommittee's report, many of the potential problems and hindrances to the development of additional energy options have been cited. This was not done to dampen support in any way for these programs. This Subcommittee urges continued support for development of non-nuclear resources. However, in light of the problem areas noted, this Subcommittee believes that, for purposes of evaluating the breeder program, conservative estimates should be made of the contribution that these alternate energy options can make to the electrical supply for the future. Therefore, we have used the lower ranges of percent of the values shown in the table on page 45.

Conclusions

Based on testimony from the ERDA and from a number of other experts, the Subcommittee concludes that energy production will be as shown in fig. 3 on page 39.

The Subcommittee strongly endorses the substantial increases in funding for alternative energy options, including solar and geothermal power, recently approved by the Congress. The Subcommittee accepts the ERDA projections for the rate of commercialization of alternative energy sources for meeting future energy needs. The Subcommittee notes, however, that even if these projected energy contributions from solar, geothermal and other alternative technologies were to be doubled our fundamental conclusions regarding the need for nuclear power would not change significantly. (Waste conversion is not included in this assumption as waste is a finite resource and cannot be arbitrarily doubled.)

Recommendations

The Subcommittee recommends continued vigorous research and development and funding of alternative energy options, maintaining at all times a realistic perspective of their potential.

D. URANIUM RESOURCE AVAILABILITY

Conclusions

The Subcommittee believes that the ERDA forecast of 3,600,000 tons of uranium at a cost of $30 or less per pound is the most prudent projection on which to base energy plans. It is recognized that these numbers may change as the findings of the National Uranium Resource Evaluation program become available.

The Subcommittee concludes that the uranium supply forecast by ERDA will be inadequate to provide for the nuclear power projected in this report beyond the mid 1990's. The utilization of the breeder concept would increase the energy potential of the presently projected 3.6 million tons of uranium such that it would become equivalent in energy output to about 126 million tons of low cost uranium, an amount of nuclear fuel sufficient to supply nuclear powerplants for centuries.

Uranium is the primary fuel used by present day light water reactors. The uranium resource base is a critical element in the debate over the need for breeder reactors and the timing of their introduction into commercial use by the electric utility industry.

The only uranium resource projections reported to the Subcommittee were those made by AEC/ERDA and the Electric Power Research Institute (EPRI). The AEC/ERDA forecasts, which were considerably lower than that of EPRI, were cited by such organizations as the Energy Resource Council, the Federal Energy Administration, the Federal Power Commission, Edison Electric Institute, National Rural Electric Cooperative Association, individual electric utilities and reactor manufacturers as the most likely base on which to plan future uranium availability levels. As discussed earlier, uranium availability is a key issue on which reactor concept development plans are made. The EPRI forecast was the preferred forcast of the Natural Resources Defense Council, Inc. and was mentioned, along with the ERDA forecast, as a possible outcome by a reactor manufacturer.

Several people reported to the Subcommittee their beliefs that the uranium supply would be larger than that estimated by ERDA, but did not cite numbers. They did not appear to base their beliefs on analysis or specific information. One such respondent supported his projection only by saying "The history of mining suggests the likelihood of further domestic supplies of uranium."

A summary of the ERDA and EPRI estimates and the data on which they are based follows.

ERDA published its latest uranium resource report on January 1, 1975, as follows:

[Thousands of short tons of U_3O_8]

Production cost in dollars per pound U_3O_8	Ore reserve	By-product**	Potential* resource	Total (rounded)
$8 or less	200	0	530	700
$10 or less	315	90	1,000	1,400
$15 or less	420	90	1,500	2,000
$30 or less	620	90	2,900	3,600

*The amount of uranium estimated as potential largely remains to be discovered and developed.
**The by-product quantity is that estimated to occur as a result of the production of phosphate and copper through the year 2000.

ERDA believes its uranium resource projections are based on the best available data and estimating techniques. According to Mr. Robert D. Nininger, Assistant Director for Raw Materials, ERDA, ERDA's estimate of reserves is based on data which mining and milling companies have been submitting to AEC since the 1950s concerning ore reserves, mining and milling programs and production

costs. ERDA believes that its uranium resource estimating program is unique in the Government and that no equivalent program nor depth of information exists for any other mineral.

Mr. Nininger reported that ERDA bases its resource estimates "on economic parameters to reflect the uranium supply potential—the amount of uranium that could be produced in specific cost ranges, with existing technology, within acceptable economic and environmental constraints and on a time frame consistent with demand." Experienced uranium geologists estimate potential resources based on industry data, field examinations, available geologic reports, discussions with other Federal, state and university geologists, as well as their own experience and knowledge. They examine and judge each geographic area on key geologic characteristics and compare them with areas of known uranium reserves and ore controls.

ESTIMATED URANIUM RESERVES

In 1974 ERDA estimated uranium reserves to be 2.4 million tons. ERDA's 3.6 million ton current estimate does not mean that 1.2 million tons have been found in the past year. The 3.6 million ton figure reflects a new definition of potential resources which includes more speculative categories of resources than were included in the previous estimate. A significant part of this postulated increase is in the low reliability categories of possible and speculative reserves. A large portion is in the $15 to $30 cost increment for which data are not well developed and mining experience is lacking.

If ERDA's recent estimates prove correct, the size and composition of the resource base have serious implications for the nonbreeder reactor power program. Information provided to the Subcommittee indicates that more than the approximately 700,000 tons (620,000 of reserves and 90,000 of byproduct) of reasonably assured reserves will be needed over the lifetime of reactors presently operating, under construction, or on order. Thus, plants that will be contracted for from now on will depend for fuel on "potential resources" which have not as yet been discovered. Several people reported that at some time during the 1900's all of the "potential resources" will also have been committed to the lifetime needs of new reactors. If converter reactors are to be built after this time, they will depend for fuel on either uranium which has not yet been projected to exist as "potential resource," on higher cost uranium from low grade ore deposits, or on recycled plutonium.

ERDA projects that another 5,000,000 tons of uranium exists in low grade deposits at a cost of perhaps $100 per pound and another 8,000,000 tons in even lower grade deposits at a cost of perhaps $150 per pound. While on economic terms alone, it might be justified to use uranium from such low grade ores, the logistical and environmental problems would be substantial. These problems relate to the amount of ore that must be mined when it is of such low grade. For example, in "An Assessment of Economic Incentives for the LMFBR," Messrs. Stauffer, Wycoff, and Palmer estimated that in the year 2000 about 140,000 tons of U_3O_8 will be needed for reactor fuel. If this requirement were to be met with low grade ore (shales), it would require mining nearly 8 million tons of ore per day. This is over five times the present

rate of coal mining which is 1.5 million tons of coal per day. The Federal Power Commission has speculated that the environmental consequences of such extreme measures are likely to preclude them from being realized.

Mr. Milton F. Searl developed the EPRI uranium resource forecast by extrapolating from ERDA data to obtain the expectation of finding a given amount of uranium below a cost of $100/pound of U_3O_8. His analysis projects that for the whole United States the probabilities are 50 percent that there is more than 13.2 million tons and 5 percent that there is more than 28.9 million tons of uranium.

From discussions between Subcommittee members and European officials, it appears that the latter project the world's supply of uranium to be about 10–13 million tons. They are also planning on the assumption that each country with a nuclear program will get a fair share of the world's uranium supply. It therefore appears that ERDA's estimate of U.S. uranium reserves is consistent with projections of free world uranium supply and that the United States cannot reasonably expect to obtain much more of the world's uranium than is found in the United States.

The estimates by ERDA and Mr. Searl differ greatly and suggest different decisions on the need and timing of breeder reactors. ERDA's estimate calls for bringing breeders on line as soon as possible. Mr. Searl's estimate suggests breeder commercialization could be delayed.

It is not presently possible to state with absolute certainty which of these estimates is correct because a theoretically sound and reliable foundation for forecasting mineral resources simply does not yet exist. Only additional detailed study and extensive exploration can resolve the question of how much uranium can be found in any price category; however, the degree to which a policy maker should rely on either the ERDA or Searl estimate must be influenced by which estimate appears most reliable and in this instance that would be dependent upon the opinion of experts and the track record of geological forecasting techniques. The Electric Power Research Institute, for which Mr. Searl made his uranium supply projection, prepared are port for the Subcommittee in which it commented on the reliability of both estimates. EPRI's view is that the ERDA data represents a prudent view of the possible extent of our domestic uranium ores and, as such, is a reasonable basis for long-range planning. EPRI believes ERDA's projection gains support from the fact that exploration in geologically interesting areas during the last 15 years has disclosed no new uranium bearing districts. EPRI pointed out that the last major find was 17 years ago and it increased our reserves by only 25%, yet the exploration activity since 1960 has been three times greater than all previous exploration. EPRI adds the caveat that ERDA's resource projections beyond the proven reserves of 700,000 tons are judgmental and require some confirmation of their realism by actual exploratory findings. Until such additional data are developed, the uncertainty of these projections should be borne in mind.

EPRI reported to the Subcommittee that the estimate done for it by Mr. Searl is a more speculative view of the possible amount of domestic uranium. Searl takes account of the fact that much of the country has not yet been thoroughly explored and that 85% of the total known uranium supply is in only two states. In addition, Searl

pointed out that additional uranium resources above those estimated by ERDA may exist in present producing regions and in new producing regions where large areas are regarded as potentially productive by geologists.

Further comments on the caution which should be exercised in evaluating the EPRI-Searl forecast were presented in a report submitted to the Subcommittee by Thomas Stauffer and Ulrich Petersen of Harvard University. They pointed out that:

> . . . the procedure used by EPRI is only a gross approximation, the kind of 'horse-back guess' one makes in the absence of more reliable geological estimates. It is the type of answer one might expect on the spur of the moment from an economic geologist or a mining engineer experienced in uranium deposits and their exploration. It is not based on a systematic analysis of the probabilities and costs of finding uranium deposits in potential ore bearing ground, but rather on that subjective cumulate called 'experience.' When one addresses this question to such a geologist or engineer, one has to weigh heavily his practical experience and judgment in the subject and one is aware of the fact that such an answer can at best only be an educated guess of the order of magnitude involved.

Past experience with forecasts of mineral resources suggests an additional element of caution due to the present lack of sound and reliable forecasting techniques. An indication of the accuracy of mineral forecasts can be seen in projections for U.S. oil reserves. Until just a few years ago various techniques which relied on geological extrapolations had been used to project that more than 400 billion barrels of oil remained to be discovered in the United States and on the outer continental shelf. This extrapolation promised domestic resources equal to 50 years or more of 1973 level oil requirements. On the basis of more recent research maximum potential oil resources are now estimated by most parties at around 100 billion barrels, not all of which is either discoverable or producible. The 75% reduction of forecast oil reserves at a time when rising oil prices and the embargo made the existence of these reserves so important indicates how risky it can be to base policies upon imprecise resource predictions.

NATIONAL URANIUM RESOURCE EVALUATION PROGRAM

In recent years the AEC has been aware of the need to develop a more reliable estimate of uranium resource projections. AEC therefore undertook and ERDA is continuing a study of the entire country, called the National Uranium Resource Evaluation program, to develop a comprehensive national uranium resource assessment. In this project, the country has been subdivided into 20 major geologic areas and a number of smaller subareas, each of which will be studied, comparing its characteristics with those of known uranium districts in the U.S. and other countries. This program is scheduled to produce a preliminary estimate of domestic uranium resources by January 1976, and an indepth appraisal by January 1980.

Other factors which policy makers should consider in relation to uranium resource projections are the consequences of not having enough uranium to supply fuel for a selected energy strategy. For example, what consequences will ensue if breeder introduction is put

off on the basis of a high uranium forecast and that forecast turns out to be a gross overestimate of reality? One can project that the consequences of a uranium shortage would probably be similar to the consequences presently being experienced from shortages of oil and gas. These include reduced economic growth, increased unemployment, and more costly fuel.

Conclusions

The Subcommittee believes that the ERDA forecast of 3,600,000 tons of uranium at a cost of $30 or less per pound is the most prudent projection on which to base energy plans. It is recognized, however, that these numbers may change as the findings of the National Uranium Resource Evaluation program become available.

The Subcommittee concludes that the uranium supply forecast by ERDA will be inadequate to provide for the nuclear power projected in this report beyond the mid 1990's. The utilization of the breeder concept would increase the energy potential of the presently projected 3.6 million tons of uranium such that it would become equivalent in energy output to about 126 million tons of low cost uranium, an amount of nuclear fuel sufficient to supply nuclear powerplants for centuries.

Recommendations

The Subcommittee recommends that the ERDA vigorously pursue its National Uranium Resource Evaluation Program to establish projections of the uranium resource of this Nation with the greatest possible accuracy.

This Nation should also pursue technological options which will extend the energy potential of our uranium supply.

E. NEED AND TIMING OF THE BREEDER PROGRAM

Conclusions

The Subcommittee concludes:

1. Continuation of the LMFBR breeder development program, as a high priority effort, is essential to the energy future of this Nation.

2. The breeder is needed no later than it will become commercially available under current development plans, i.e., the early 1990's.

3. Vigorous pursuit of LMFBR development at this time, including construction of demonstration plants, is essential to provide adequate information on which to base future decisions concerning commercialization of breeder technology. The collection of the information does not constitute a commitment to future commercialization.

4. An aggressive program of research and development on the safety and environmental impacts of breeder commercialization must be continued as a top priority effort. Our present knowledge and understanding of these issues suggests no reason for delaying the breeder program.

5. Substantial reliance on foreign technology beyond the establishment of information exchange agreements is not a satisfactory substitute for development of a breeder reactor industry in the U.S

6. A very substantial review effort on breeder development plans, approach and strategy has been and continues to be made by advisory groups and others. The conduct of such studies should not be allowed to occasion delay in the program.

As discussed in Section III. B, the consensus of information presented to the Subcommittee is that both coal and uranium will be needed as the primary fuels for electric power production throughout this century, and into the 21st century. However, based on the availability of uranium resources (Section III. D), and on anticipated energy use trends (Section III.A), existing and projected uranium supplies will be inadequate to carry the load projected for nuclear power if "burned" in current fashion in converter reactors such as the LWR. The reason for this shortfall is that LWR's can utilize only 1–2 percent of the energy available in uranium, because they are dependent primarily on the fission of the scarce uranium isotope U–235. Breeder reactors, on the other hand, are capable of converting non-fissionable uranium or thorium into fissile material (Pu-239 or U–233, respectively) at a rate faster than the material is consumed, and have, therefore, been proposed as a means of economically extending the use of large, otherwise unusable domestic uranium and thorium ore resources. Appendix 4 provides further information on the background and workings of breeder reactors.

Several types of breeder reactors have been studied over the years, and research and development on several breeder concepts in addition to the LMFBR continues today. The types of reactors currently included in the breeder program are the light water breeder reactor (LWBR), molten salt breeder reactor (MSBR), gas-cooled fast breeder reactor (GCFR), and the LMFBR. Based on its potential economics, broad technical base, and the interest of electric utilities and reactor manufacturers, the LMFBR has been selected as this Nation's highest priority breeder reactor development program. Several other industrially advanced nations such as the U S.S.R., Federal Republic of Germany, France, the United Kingdom and Japan have similarly chosen the LMFBR as a priority effort in their nuclear programs.

The national breeder reactor program's major effort is on the LMFBR concept, with smaller backup efforts comprising less than 15 percent of the total program on the other breeder concepts listed above. The LMFBR program has as its objective the establishment of a broad technological and engineering base sufficient to permit the industrial involvement required for a competitive commercial industry. It includes development and demonstration of the technology for a safe, reliable, economically viable and environmentally acceptable breeder reactor. An essential element of this program is the construction and operation of a mid-sized demonstration plant, the Clinch River Breeder Reactor (CRBR). If this project is successful, a larger, near-commercial size, reactor would probably follow, and would also be a joint industry-government funded project. The goals, approach and timing of the CRBR project are discussed further in Section III. F.

With this background in mind, and in view of the concerns that had been expressed in Congress and by the public with respect to various aspects of the LMFBR program, the Subcommittee undertook to examine the need for the program, and its potential

benefits and risks. It should be noted at the outset that this examination is not the first nor the only such review of the Nation's nuclear power program, or elements thereof. The Joint Committee on Atomic Energy is well aware that reexamination of nuclear programs and their priorities had been a continuing activity of the Atomic Energy Commission for many years, as well as a matter in which the Committee itself has participated to an important extent.

As part of the data base on this subject, one may arbitrarily start with the AEC's 1962 Report to the President, which examined the reactor development programs then in progress and set forth the promise of breeder reactors. The 1967 Supplement to this report indicated the changes that had occurred since 1962 and considered the ongoing AEC reactor programs in relation to the recommendations of the 1962 report. This supplement reaffirmed the need for the breeder, particularly the LMFBR.

Also in the late 1960's a series of more extensive evaluations was conducted of various reactor concepts to provide a basis for their consideration in the overall reactor development program. The concepts evaluated included heavy water moderated organic cooled reactors, heavy water moderated boiling light water cooled reactors, high temperature gas cooled reactors, steam cooled fast breeder reactors, and gas cooled fast breeder reactors. Additional evaluations continued into the early 1970's, including cost-benefit analyses of the U.S. breeder reactor program, and examination of the molten salt breeder reactor and the gas cooled fast breeder reactor. These concept evaluations considered the attractive features and problem areas associated with each concept, and were directed primarily toward providing a view of the technology and engineering development efforts and the associated government and industrial commitments which would be required to develop the concepts into safe, reliable and economic power sources for central station application.

Other reviews were conducted by the Cornell Workshop Panel, the conclusions of which were reflected in the report "The Nation's Energy Future" submitted to the President in December 1973; the Nuclear Fission Subcommittee of the President's Council on Energy Research and Development, the conclusions of which were reported in a December 1974 letter to the Chairman of the Atomic Energy Commission; and the General Advisory Committee of the Atomic Energy Commission.

Among the more recent and comprehensive evaluations of the breeder program and nuclear and non-nuclear alternatives are the "Report of the LMFBR Program Review Group" (commissioned in late 1974 by the Chairman of the Atomic Energy Commission), the Environmental Statement on the LMFBR Program (published in "Proposed Final" form in December 1974), and the National Plan for Energy R. & D.: Creating Choices for the Future, which was submitted to the Congress by ERDA on June 30, 1975. These reviews have generally reaffirmed an urgent need and high priority for the LMFBR program.

At the same time, the JCAE is also aware that similar reviews have been and continue to be conducted by organizations with a less optimistic view on the future of nuclear power and breeder reactors, and by other government agencies. The results of these reviews have in some instances been markedly different from those obtained by

the nuclear community. For example, the report "Bypassing the Breeder", issued by the Natural Resources Defense Council (NRDC) in March 1975, takes strong exception to the government's plans for breeder development. Similarly, several letters of comment on the LMFBR Environmental Statement by NRDC, the Scientists' Institute for Public Information (SIPI), the Mid-America Coalition for Energy Alternatives, the Hudson Institute, and others raise numerous issues against proceeding with the breeder. Other groups and individuals, some local governments, and several members of Congress have also expressed objections to the breeder. Finally, the General Accounting Office, in a continuing series of reviews has pointed out shortcomings and various problem areas in the conduct of the LMFBR program. Thus, the case for breeder reactors would not appear to be clear cut or one-sided, and the Subcommittee set out to determine the validity of the issues raised and the extent to which they are supported.

Need for the LMFBR

As noted in Section II. B, the major avenues by which information was presented to the Subcommittee were letters, public hearings and on-site examination of foreign breeder facilities. In addition, the Subcommittee had the benefit of staff review of existing publications pertaining to the breeder program and discussion thereof. In all of these forums, the overwhelming view expressed was that the breeder is needed, and most respondents felt that this need is urgent. Several replies took a middle-of-the-road position, implying that the need and timing for the breeder are uncertain, but that some breeder program would probably be needed eventually. A somewhat larger, although still a minority grouping of organizations and individuals, generally known to oppose nuclear energy, reported that the breeder definitely was not needed. A few people in this latter group, following discussion at the hearings, conceded that the breeder program was needed, or at least that R. & D. should proceed, although they had reservations regarding the LMFBR's timing and approach, or on the plans for construction of the demonstration plant (CRBR).

The Subcommittee was impressed that those government agencies with responsibilities for planning or providing for the Nation's energy needs supported the urgent development of the breeder, as did almost all industrial or utility organizations queried. The main reason offered for the need for a commercial breeder on a timely basis was its ability to provide sufficient fuel for future electrical generating requirements. In addition, many breeder supporters noted its attractiveness from a cost-benefit basis, i.e., future projected savings in fuel costs by the breeder will far outweigh development costs. Also cited was the inability of alternative energy sources to provide needed energy on a timely or economic basis. In particular, it was noted that both coal and nuclear power are needed to meet future energy requirements, but without the breeder reactor, nuclear power would not be able to handle its share of the load due to rapid depletion of nuclear fuel resources. Other reasons advanced in support of breeder development were: its capability to eliminate the environmental effects that would be attendant to the extensive use of low grade uranium ores (which would likely have to be resorted to without

the breeder) and the accompanying use of massive quantities of coal, the ability to conserve coal which has unique uses as a chemical feed stock; the need to provide adequate energy supplies to maintain economic growth and satisfactory living standards; the belief that current projections of reduced energy growth rates in the future are optimistic, and represent an improper basis on which to make important current energy supply decisions; the need to avoid dependence on foreign fuels; and the general belief that safety and environmental problems relative to the breeder are solvable and will be well in hand by the time a decision on commercial utilization of the breeder reactor is made.

Of the several reasons cited to support the need for the breeder, the first two (uranium resource extension and a favorable cost-benefit ratio) are particularly significant and deserve further explanation. With regard to uranium reserves, it is clear that the magnitude of this resource base will be a major factor in determining the level of non-breeder reactor growth that can be attained in future years. To assess the significance of this point, one may examine the principal type of non-breeder reactor in use today, which is the light water reactor (LWR). LWR's, because they essentially make use only of the fissionable isotope U–235, require large amounts of uranium. A typical 1,000 megawatt LWR, depending on its capacity (use) factor and other assumptions, requires about 550 tons of uranium oxide (U_3O_8) for its initial loading, and then about 4,500 tons more over its 30 year projected life, for a total of approximately 5,000 tons.

The current estimated total of reasonably assured U.S. uranium reserves and potential resources is 3.6 million tons of U_3O_8. Depending upon the rate at which this resource is utilized in LWRs, which in turn depends on the energy growth rate, plant capacity, and other factors, the "available" 3.6 million tons will be fully committed by perhaps the mid-1990's. No additional converter (burner) reactors could be built after this date unless additional uranium resources are found or low grade ores are used, with their accompanying higher cost and environmental impacts. In fact, of the 3.6 million tons, only 0.6 million tons are currently identified as "assured reserves", and these are already essentially committed to LWR plants now in operation or which will be operational by the early 1980's.

A National Uranium Resource Evaluation (NURE) program is underway by ERDA to permit a more refined estimate of uranium resources and will be useful in formulating reactor development strategies. However, even a doubling of the current 3.6 million ton uranium resource projection would enable construction of converter reactors for only another 5 to 30 years depending on the energy growth rate. Similarly, the use of advanced converter reactors would, according to most estimates, conserve no more than 15–25 percent of the uranium consumed by LWRs, and the timely development and commercial acceptance of advanced converters is not a certainty. Other methods of extending uranium reserves, such as mining the tails stockpile through improved isotope separation methods, have not yet been shown to be technically or economically feasible and would only add a few additional years. Thus, breeder reactors, particularly the LMFBR, are considered by most nuclear experts as the only assured means of extending our uranium reserves and providing the nuclear

fuel needed for electricity production in the early portion of the 21st century and onward. At the same time, utilization of the breeder will greatly diminish the need to mine low grade uranium ores and will provide the most efficient use of plutonium produced in LWRs. Both these factors provide significant environmental benefits.

In a similar vein, breeder proponents believe that economic reasons as supported by cost-benefit analyses provide important incentives for LMFBR development and early commercialization. The basic argument is that the use of breeder reactors will avoid reliance on low grade, high cost uranium ores, with substantial resultant savings in fuel costs which will be passed on to consumers. These savings are estimated under all but the most pessimistic conditions to be considerably greater than development costs of the LMFBR program. Specifically, it has been reported in testimony before the Subcommittee that the LMFBR can: (1) reduce the cost of electricity to the consumer by as much as 40 percent after the turn of the century; (2) halve the cumulative requirements for mining uranium and for performing separative work between now and the year 2020; (3) provide a net savings of about $150 billion in cumulative capital requirements to the year 2020; and (4) stabilize nuclear power costs at a low level by assuring an unlimited supply of low cost fuel for all reactor types. In accordance with this approach, it is reported that each year of delay in commercialization of the LMFBR results in unrecoverable economic and environmental costs.

The ability of the LMFBR to stabilize nuclear power costs through assuring the most efficient usage of nuclear fuel is a matter of special significance, as it points up the relationship between the LWR and the LMFBR. As noted elsewhere in this report, LWR operation results in the production not only of electricity, but also of plutonium, specifically about 0.6 to 0.7 grams of plutonium for each gram of U–235 consumed. This new plutonium may be used either as a partial replacement for the U–235 fuel in LWRs, or as fuel for fast breeder reactors, such as LMFBRs. The latter use was reported to the Subcommittee as representing a much more efficient and economical utilization of plutonium. However, it was also reported, assuming that plutonium recycle is approved on safety and environmental grounds, that the plutonium produced by LWRs in the 1970's and 1980's will be used both to fuel LMFBRs as they are introduced and also to extend the use of LWRs by replacing some of the U–235 that would otherwise be required. The relative extent to which plutonium is used in LWRs and LMFBRs will depend on the number of LWRs in operation at the time LMFBRs are introduced, the rate at which LMFBRs are built, the inventory and fissile production characteristics of LMFBRs, the uranium resource situation relevant to LWRs, and the relative economics of plutonium utilization in LWRs and LMFBRs at the time under consideration. As the number of LMFBRs increases, the relative amount of LWR-produced plutonium required to fuel LMFBRs will decrease, since LMFBRs will, it is assumed, eventually fulfill the major portion of the nuclear power demand and produce plutonium in excess of their needs. The Subcommittee was advised that in this long-term situation, the strong coupling characteristic of the LWR and LMFBR reactor combination will result in economic optimization of the use of excess plutonium, with the

eventual result that the cost of nuclear power will be essentially independent of the price of uranium due to the transition to a breeder energy economy.

Another point made in regard to assessing the need for the breeder is that the additional uranium resource base that would be made available by breeder technology should be examined against the resource base of other fuel sources. Figure III.E.–1 provides this comparison. It is seen that the 130,000 Quads* made available by the breeder is almost 1800 times the total amount of energy (73 Quads) consumed in the U.S. in 1974. This 130,000 Quads is also equivalent to over 20,000 billion billion barrels of oil, or over 1000 times the estimated reserves in the Alaskan north slope. At a breeder development cost of $10 billion, this uranium energy would become "available" at a cost of about 1/25 of a cent per barrel equivalent. This can be compared to the cost of the Alaskan pipeline alone, which is about 30¢ per barrel of oil or 750 times as much per unit of energy. Other estimates of the equivalency of nuclear energy to oil were made in section III. B., wherein the cost savings already attained through the use of LWRs rather than imported oil for power production were reviewed.

[Figure III.E.1 follows:]

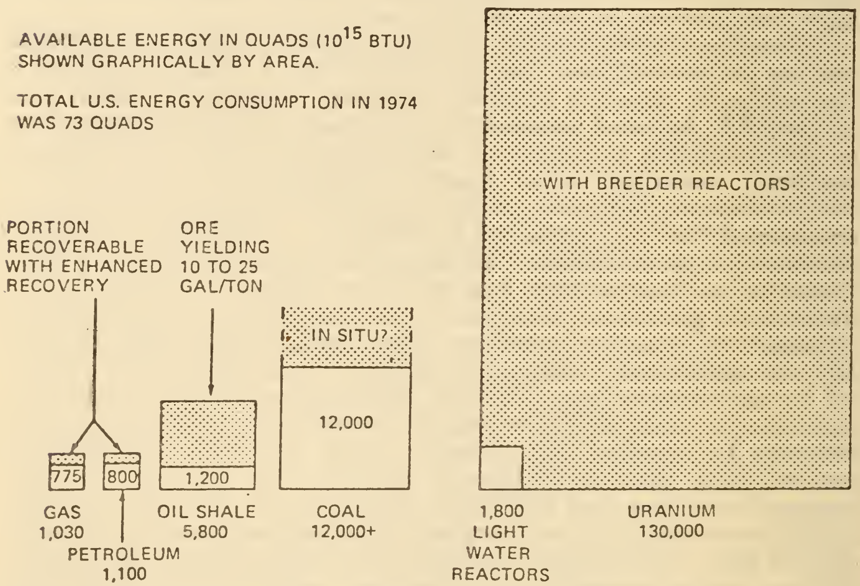

Figure III.E-1 Available Energy from Recoverable Domestic Energy Resources*

*Source: A National Plan for Energy Research, Development and Demonstration (ERDA-48), June 1975.

*A *Quad* is a unit of energy equal to a quadrillion Btu's. (1,000,000,000,000,000 Btu's)

The reasons reviewed above in support of the need for the LMFBR were also considered by the Energy Research and Development Administration (ERDA) in two actions taken during the latter part of the Subcommittee's review of the LMFBR program. These were the submission to Congress on June 30, 1975 of a National Plan for Energy Research, Development and Demonstration, and the public release of the ERDA Administrator's findings following a detailed review of the Proposed Final Environmental Statement on the LMFBR Program. On the basis of these actions, The Administrator reported ". . . I am absolutely convinced that we must pursue research, development and demonstration of the LMFBR concept as a matter of high priority . . . there is no prudent alternative to this course of action . . . For the nation's future, we simply must pursue this energy option vigorously and responsibly . . ." The Subcommittee viewed this expression of support by ERDA as a significant firming of the Administration's position on the LMFBR program.

Reasons Cited in Arguments Against the LMFBR

The Subcommittee also heard testimony and received information to the effect that the need for the breeder had been overstated, and that the projected benefits were not to be had. In general, those groups or individuals opposing the breeder were found to do so based on the same general arguments that the proponents cite in favor of its development, but the opponents generally place a different interpretation on the factors cited above. For example, the opponents suggest that development costs will outweigh savings in fuel costs, (i.e., that cost benefit analysis supports the abandonment of the breeder rather than its development), that AEC–ERDA estimates of uranium resources are too conservative (and that substantial quantities remain to be discovered at economical prices in this country), that energy demand will be less than projected by breeder proponents in future years, and that safety and environmental problems are beyond man's control. In particular, opponents cite the toxic nature of plutonium, the need to safeguard nuclear material (i.e., protect it against diversion to non-peaceful uses), the lack of assured long term waste storage procedures, and uncertainties regarding fast reactor safety as reasons why breeder development should be abandoned. These latter factors are discussed at greater length in section III. G.

These arguments against the breeder generally coalesce in comments on the cost-benefit analysis, which has been reported in testimony to be very sensitive to a number of assumptions, among them projection of domestic uranium supply, the future demand for electricity, and the capital cost differential between LMFBRs and conventional nuclear reactors (LWR's). Some witnesses suggested that when less optimistic values of these factors are assumed, the cost-benefit analysis shows that the LMFBR is not economically advantageous. On this basis, the program would be judged to be either premature or unnecessary.

Proponents of the breeder also pointed out items on the minus side of the ledger—the dismaying rise in cost estimates, the retreat from original time schedules, the management complexity of administering

the LMFBR program and the CRBR project, and especially, the continuing challenge to prove to the American people that the potential hazards involved are minimal, that appropriate actions are being taken to safeguard the public, and that ultimate benefits far outweight the costs. These items were also of great importance to the Subcommittee in its deliberations on the need for the breeder program.

Alternate Breeder Concepts

A corollary question considered by the Subcommittee was, assuming a breeder reactor is considered to be needed, whether or not this country should continue to put its major effort on the LMFBR, or if more (or less) effort should be devoted to alternate breeder reactor concepts. Again, respondents were essentially unanimous in agreeing that the LMFBR should continue to be the focus of breeder efforts and receive top priority. This conclusion was voiced even by critics of the breeder program, if they agreed that some breeder program was needed. Some of the information presented suggested that alternate breeders such as the GCFR or LWBR should continue to be funded at about the same relative level of effort as currently provided. A minority viewpoint was that funding for the GCFR and MSRB should be increased, although there was little suggestion that this should be accomplished at the expense of the LMFBR. The thrust of increasing attention on some alternate breeders was to gain additional information on the thorium fuel cycle (see discussion later in this section). However, the clear consensus was that in view of over 25 years of LMFBR design and operating experience, the relatively advanced state of LMFBR technology over alternate breeders, and its much greater likelihood of achieving timely commercial acceptance, the LMFBR should continue to receive primary emphasis in the national breeder reactor program.

A closely related matter considered as part of the Subcommittee's review was whether or not the overall LMFBR program objectives, content and approach are correct, and what steps can be taken to minimize the costs of the program, and improve performance with respect to program schedules. With regard to overall objectives and approach, the great majority of respondents was again enthusiastic about the program goals and the means proposed to achieve them. Several witnesses were generally supportive but suggested substantial modifications, such as the use of foreign technology, greater industrial and utility involvement, or a stretch out (or acceleration) of the program. A few respondents, who as noted before, are generally viewed as opposing nuclear energy, found the whole program premature and ill-advised. They recommended steps such as successful operation of the FFTF before a demonstration plant is built, if at all.

Recommendations to minimize costs (besides canceling the CRBR) were to use foreign technology, maintain tight control over the project, keep goals in mind and work towards them without continued reassessment. Some respondents warned against trying to build an elegant LMFBR before the basic utility oriented design is well in hand. Most felt that industrial participation is adequate. One pointed out that such utility and industrial involvement is being

reduced by the recent CRBR reorganization, and another argued against the need to contribute financially in order to participate. A few thought that industry should do everything but pay for it, and several felt that industry isn't needed at all, at least until commercialization occurs.

Reliance on Foreign Technology

Of the steps suggested for improving program performance and reducing costs, that of placing greater reliance on foreign technology seems to generate the most interest (and perhaps controversy) among both breeder proponents and opponents. This approach was explored by the Subcommittee not only in its regular briefings and hearings, but also during its trip to breeder facilities in several European countries (see section II.B.4). In general, the question rests on the premise that there are active LMFBR development programs in several foreign countries, that these countries are for the most part further advanced than the United States in terms of building and operating pilot plant or demonstration LMFBR reactors, that there are some similarities and differences between the foreign programs and the U.S. program, and that the United States should consider whether any savings can be made in its overall LMFBR program or major elements thereof (e.g., CRBR) by greater utilization of foreign information, technology or facilities.

While it appears that some savings might be obtained by this approach, several problems have also been brought to the Subcommittee's attention. The degree of savings and accompanying disadvantages would depend on the extent to which foreign technology is relied upon as a substitute for this country's own LMFBR program. Briefly, the problems that have been raised are that:

1. It is undesirable for the U.S. to depend on foreign designs for a major future energy option which is still under development,
2. Foreign designs would require substantial modification to meet U.S. safety and licensing requirements,
3. Reliance on foreign technology would result in failure of the U.S. to develop its own LMFBR technology and industrial base,
4. Purchase of foreign technology or components would have an undesirable effect on the U.S. balance of payments deficit, and
5. Foreign LMFBRs may not have the performance characteristics desired by U.S. utilities.

An analogy with our current dependence on foreign oil has been made by several respondents as a basis for suggesting that our reliance on foreign suppliers of LMFBR technology should be minimized. At the same time, it has been suggested that much useful information has been developed in foreign breeder reactor programs, and that this Nation and others could benefit from expanded information exchange agreements.

A somewhat more detailed, yet concise statement of the pros and cons of various degrees of reliance on foreign technology was conducted by the LMFBR Program Review Group in their previously referenced report. Their analysis is particularly germane to the Subcommittee's review and is reproduced herein as Appendix 5.

Program Costs and Capital Costs of Breeders

Other questions examined by the Subcommittee included the total projected R. & D. costs for the LMFBR and their means of recovery, the predicted capital costs of commercial LMFBR's and the methods to provide that capital, and the overall issue of whether or not the LMFBR would be economically viable. The general consensus of information presented was that the $10.6 billion ERDA figure for the total LMFBR R. & D. program was a reasonable estimate, although a few respondents voiced strong feelings that previous inabilities to meet cost estimates meant the figure would go much higher. Most respondents recognized that although the costs would initially be borne by taxpayers, they would be recovered later through lower power costs (i.e., taxpayers are also utility customers). This aspect was discussed earlier in more detail under the subject of cost-benefit analysis.

Capital cost estimates ranged from the same as LWR's to about 25 percent greater, depending on assumptions as to timing, learning curves, etc. Most witnesses felt that utilities would be capable of raising the necessary funds in the required time frame. As to fuel cycle costs, a wide range of figures was reported to the Subcommittee, but the consensus seemed to be that LMFBR fuel cycle costs would still result in substantial savings over LWRs. The consensus on overall economics was that the LMFBR would be viable, although the timing of commercialization was debated, and several anti-nuclear witnesses reported the LMFBR would be neither economical nor desirable.

Program Timing

The question of timing for the LMFBR came in for considerable attention in the information presented to the Subcommittee. It involves several fundamental issues reviewed earlier in this report, particularly energy trends and availability of uranium, as well as the many topics addressed in this section. As on other subjects, the issue of timing produced a wide polarization of views, but, as before, a consensus was clearly evident. That consensus was that the breeder is needed by about the time it would become commercially available under current development plans, i.e., the early 1990's. Several witnesses suggested this timing should be accelerated, noting that if energy demand returns to near-historical levels, the breeder may already be too late. Acceleration of breeder development plans was also suggested on the grounds that other energy resources, e.g., oil, gas and even coal, are being depleted and denied to future generations. By bringing the breeder on-line at an earlier date, these resources would be conserved.

The main argument for early breeder development and commercialization, however, is that of uranium resource availability. Of the 3,600,000 tons of uranium resources, only 600,000 tons are classified as assured reserves, and as noted earlier this amount will be committed to LWR's by the early 1980's. The remaining quantity will last into perhaps the mid-1990's, but it must be noted that this 3,000,000 tons of "potential resources" ranges in availability from probable to speculative. If a significant portion of these potential resources do not materialize, according to most witnesses, the need for the breeder may become urgent well before the mid-1990's.

As was the case with all other issues examined, a substantially different minority view was also presented to the Subcommittee. On the subject of timing, this view is that based on future energy demand being lower than proposed by AEC–ERDA, and on the "likelihood" of additional economically recoverable uranium resources being identified, the need and timing for the LMFBR is uncertain at best. The fact that the breeder's main contribution to energy generation is not anticipated to occur until after the year 2000 has been viewed by some as grounds for suggesting that the LMFBR is not needed until that time, and that its development may therefore be delayed. Managers of the breeder program, on the other hand, point out that any delay now in important program elements such as CRBR would lead to a significant lessening of momentum, including loss of design and management personnel, and greatly increased future costs when the program again gears up. Of further consequence is the very real likelihood that, if delayed, the breeder will not be available when and if needed.

The position was taken by the Environmental Protection Agency (EPA) in testimony and subsequent correspondence with the Subcommittee that some flexibility would appear to exist in the date by which LMFBR commercialization would be required. Specifically, based on the energy projections in the Project Independence study, EPA reports a delay of four to twelve years in commercialization may be possible (beyond the 1987 base case) without losing the uranium conservation value of the breeder. Administrator Russell Train made it clear that EFA was not proposing such a delay be made, but that flexibility may exist in the future. At this time, EPA supports and favors early demonstration of breeder technology, as do all other government agencies concerned with energy supply. The Federal Energy Administration (FEA) and the Federal Power Commission (FPC), for example, reported there was an urgent need for the LMFBR on an early schedule.

The subject of LMFBR commercialization itself has generated some confusion and controversy, and was included among the various topics examined by the Subcommittee. The relevant issue seems to be whether or not proceeding with the LMFBR R. & D. program now, specifically with the CRBR project, represents an irreversible commitment to commercialization. This issue is, perhaps, best understood by examining the meaning of the term commercialization. For purposes of discussing a means of electricity generation, commercialization may be defined as development of a technology to the point that it may be considered a viable option for energy production, i.e., it is available, reliable, and economically competitive with other energy production options. Whether or not a commercial option is exercised (i.e., a number of plants of that type are built) will depend on the relative technical and economic merits of that option in comparison with other available options. The *decision* on exercising an option will rest primarily with the utility industry, rather than the government, and will be influenced to no small extent by public acceptance of the technology involved. The time frame in which an option may be said to be exercised must also be recognized as being at the time the technology is needed to be put into use, not when it is being developed. Finally, it is self-evident that no energy option, including the LMFBR, should be exercised if it is found to be unsafe or environmentally unsound.

With this approach as background, it was reported to the Subcommittee by ERDA, the government agency responsible for developing the LMFBR, that proceeding with the current LMFBR program, including the CRBR project, in no way represents a commitment to commercialization nor does it prejudge any decision concerning the eventual commercialization of the technology. The government and industry, under this approach, will proceed with development and demonstration of LMFBR technology, fully recognizing that a decision on committing to this technology is some time away, being dependent on when the LMFBR is needed (in accordance with the timing arguments presented earlier) and on the development of further information and successful resolution of questions on the economic feasibility and environmental acceptability of widespread commercial use of LMFBR's.

This position is considered to be consistent with that taken by EPA, who reported to the Subcommittee that various environmental uncertainties prevent a reliable forecast at this time of the impacts of large scale LMFBR commercialization. EPA also stated that it could not support a decision at this time to commit the Nation to future full-scale commercialization of the LMFBR. However, one might suggest this position clouds the real issue, which is not that of making a decision on commercialization at this time. Indeed, the General Accounting Office in its most recent (July 31, 1975) analysis of issues on the LMFBR program, reported to the Congress that

> . . . the LMFBR program should be clearly identified and recognized for what it is: an R. & D. program. There has been premature concern and emphasis on commercializing the LMFBR at a time when the Nation is years away from demonstrating that commercial-size LMFBR plants can be operated reliably, economically, and safely. It is unlikely that utilities will make major financial commitments in advance of such proof, which may not be available until the mid-1980's.

LMFBR Program After CRBR

Demonstration of LMFBR operability, safety, economics, and other characteristics is to be accomplished in the United States by the Clinch River Breeder Reactor project, which is discussed further in section III.F. In addition to considering the need for the CRBR, the Subcommittee also received information on the need for and contents of the LMFBR program after CRBR. Issues in this time period (after 1980) were not so clearly defined in testimony and other sources as were those discussed in earlier sections. The reason for this situation lies perhaps in the hypothesis that breeder opponents believe that the LMFBR program itself is ill-advised, and that CRBR should be either cancelled or deferred. Thus, clear-cut alternatives for a post-CRBR LMFBR program were not highlighted by opponents as they generally felt the program should not get that far.

On the other hand, those persons and organizations who feel the LMFBR is needed have noted several issues which will come in for increasing attention as planning for the post-CRBR phase of the program continues. These include the size, timing and funding arrange-

ments for the next plant, or Near Commercial Breeder Reactor (NCBR, if one is to be built; the means by which major components shall be tested, and the need for a new large Plant Component Test Facility (PCTF) or modification of the existing Sodium Components Test Installation (SCTI); the scope of continuing LMFBR safety R. & D., focusing on the need, timing and objectives of a Safety Research Facility (SAREF); the means by which the goal of reducing the doubling time in LMFBRs may be achieved, including the funding and timing of the advanced fuels program, and the question of when advanced fuels should be placed in CRBR; and general questions on the relative roles of government and industry, as well as the timing of bringing the LMFBR to the point of commercial availability. The Subcommittee recognizes that these questions and other are still being analyzed by the Executive Branch and that decisions and submission of funding proposals to the Congress for some of these issues may not be made for some time.

Role of Thorium

One final question raised briefly during the Subcommittee's review was the potential use of the fertile material thorium as a means of extending our uranium resources. Thorium-232, under neutron irradiation in a reactor, can be converted into uranium-233, which is a fissionable material similar to uranium-235. The use of a uranium-233/thorium-232 fuel cycle in both advanced converter reactors (e.g., the HTGR) and breeder reactors has long been recognized as a possible supplement to reliance on the uranium-235/plutonium fuel cycle used in LWR's and LMFBR's.

Efforts are currently supported by ERDA on two breeder reactor concepts that would operate on the uranium-thorium cycle. These are the light water breeder reactor (LWBR) and the molten salt breeder reactor (MSBR). Each of these concepts has advantages and disadvantages relative to the LMFBR and to each other, and are at different stages of development. An LWBR breeding core (50 MWe) will be installed in the Shippingport reactor in 1976 to confirm the breeding capability of this system in a light water reactor plant. The MSBR, on the other hand, is in the initial R. & D. stage, and is funded at a lower level as a backup breeder concept. An advanced converter reactor (the HTGR) that also operates on this fuel cycle, although without a breeding capability, has entered the market, although its long-term commercial viability is not yet established.

Among the problems faced by reactors operating on the uranium/thorium cycle are the need for development of reprocessing methods for spent fuel, and for a process for refabrication of reprocessed U^{233} into fuel elements. The latter step is complicated by the presence of U^{232}, which results in levels of gamma radiation sufficiently high to make refabrication more difficult to accomplish.

One of the major suggestions made to the Subcommittee regarding possible use of thorium fuel cycle reactors as substitutes for the LMFBR was for additional emphasis to be placed on an advanced version of the CANDU reactor concept, a reactor type developed in Canada. As opposed to the 60 percent conversion ratio (conversion of initial fissile material into new fissile material) achieved in LWR's,

and 85 percent ratio in HTGR's, a conversion ratio of 95 percent has been suggested as possible in an advanced CANDU reactor. If achievable, and if utilized on a wide scale, such reactors could greatly extend existing uranium reserves. It has therefore been suggested that the U.S. enter into a cooperative agreement with Canada for further development of this type of reactor. It is recognized, however, that even a successful advanced converter reactor would not entirely remove the constraint of limited uranium and thorium resource availability in the manner that can be accomplished by breeder reactors.

Conclusions

Based on the information presented to it in briefings, hearings and correspondence, the Subcommittee has reached the following conclusions with regard to the need and timing for the breeder, specifically as related to the issues and subtopics discussed in this section:

1. Continuation of the breeder development program as a high priority effort is essential to the energy future of this nation. Within this context, the LMFBR is the most advanced breeder concept and has the greatest likelihood of achieving success. It should remain the focal point of the breeder program. The need for the breeder is amply justified by its capability to greatly extend our uranium resources and by the magnitude of these resources relative to other energy supplies, and also by its favorable projected cost benefit ratio. This conclusion is based on an overwhelming consensus of information presented to or studied by the Subcommittee. It is also consistent with the position of the Administration and the electric utility industry.

2. Arguments raised against the breeder on the grounds that uranium resources will be adequate or that development costs will exceed likely benefits are not justified by factual evidence, and represent a minority opinion. Additional reasons cited against breeder development on the basis of safety and environmental concerns have been substantially over-emphasized and distorted. However, some of the questions raised in this area represent legitimate concerns which have not yet been fully resolved, and must continue to be addressed in the breeder development program.

3. Substantial financial and schedular problems have beset the breeder program. While not to be dismissed, these problems generally represent difficulties often encountered in the development of high technology during inflationary times, and are not unique to breeder reactor technology.

4. Based on our present knowledge, it strongly appears that the breeder is needed no later than it would become commercially available under current development plans. i.e., the early 1990's. There is a substantial possibility that this need could develop at an earlier date. Any delay in breeder development could result in the Nation being without sufficient energy supplies, resulting in severe adverse economic impacts.

5. Vigorous pursuit of LMFBR development at this time, including construction of demonstration plants, is essential to provide adequate information on which to base future decisions concerning commercialization of breeder technology. The collection of this information does not constitute a commitment to future commercialization. The

issues of development and commercialization are separate matters. Any decision on large scale commercial deployment of LMFBRs is one that is clearly reserved for future consideration in light of information yet to be developed.

6. Substantial reliance on foreign technology is not a satisfactory substitute for development of a breeder reactor industry in the U.S. However, mutual exchange of information between the U.S. and other industrially advanced nations have proven beneficial, and should be encouraged and continued. A significant potential remains to be developed in this area.

7. The general objectives, content and approach of the LMFBR program are correct and, considering the wide range of industry, government and other views on this subject, represent a reasonable basis for proceeding with development of the technology. Plans for the latter stages of the program are, as may be expected, not as well defined as are those for current activities, and are the subject of continuing review. A very substantial review effort of breeder development plans, approach and strategy has been made over the years by government agencies and other organizations. These reviews, which are continuing, are of an overlapping nature and represent a significant expenditure of time and effort, not only for the reviewers but especially for those bearing the line responsibility for successful conduct of the R. & D. program.

8. The potential of thorium as a means of extending our nuclear fuel resources is recognized, but the designation of breeder concepts using the uranium-thorium fuel cycle as of secondary priority relative to the LMFBR remains justified.

Recommendations

1. Development of the breeder should be continued with a new sense of urgency, and the LMFBR should remain the focal point of this program. The schedule for LMFBR development should be reexamined by ERDA against the possibility that the breeder may be needed earlier than it would be available under current plans. The possible need for reoptimizing the breeder program schedule should be considered by ERDA on the basis that future energy demands may be in the upper range of those now projected, and that uranium resources may not be as plentiful as potential resource figures now indicate. This conservative approach should be viewed as a means of identifying and balancing the costs and likelihood of success of accelerated development of the LMFBR against the economic and social costs to the nation of not having the LMFBR available at an earlier date if needed.

2. The Subcommittee wholeheartedly believes and recommends that the national debate over the need for the breeder be discontinued. It should be recognized by this Nation, as it has by other industrially advanced countries, that the breeder is needed as a matter of national urgency. Those who are legitimately concerned over the safety and environmental aspects of the LMFBR should channel their efforts toward assisting in identifying and reaching solutions to these problems, rather than toward pointing to these problems as reasons for delaying or terminating LMFBR development activities.

3. The tendency toward redundant and duplicative reviews of nuclear power and the need for the breeder reactor should be reduced to a minimum. While periodic reassessments of program goals and approach are appropriate, the major review efforts by government and industry should be on narrower issues justifying greater attention, e.g., how program goals are being met, means for improving cost and schedular performance, adequacy of program management, and other topics on the order of "how best to get the job done", rather than "should we do the job".

4. ERDA should continue existing efforts and consider lending greater emphasis to the establishment of information exchange agreements with foreign countries who are also actively pursuing LMFBR development programs. These agreements should encourage free flow of technical information, assignment of personnel to foreign facilities, the exchange of study teams on particular technical areas, etc. All exchange agreements should be arranged so that the flow of information in both directions is equitable.

F. CLINCH RIVER BREEDER REACTOR (CRBR)

Conclusions

The Subcommittee emphasizes that the CRBR is an important and necessary element in the orderly progression of research, development and demonstration for a responsible LMFBR program. The Subcommittee also believes that the projected operational schedules of the FFTF and the CRBR project permit a proper use of design experience and allow for an efficient utilization of scientific and engineering manpower.

Purpose of the CRBR and Its Role in the LMFBR Program

The CRBR is intended to demonstrate LMFBR performance on an electric utility system. More specifically, it's purpose is to demonstrate technical performance, reliability, maintainability, safety, environmental acceptability and economic, feasibility of a LMFBR central station electric power plant in a utility environment and to confirm the value of the breeder concept for conserving important nonrenewable natural resources. It is further intended that this project will establish the licensability of the LMFBR in today's regulatory environment.

The CRBR is considered by proponents to be an important element in the overall LMFBR program. It is intermediate in size, 975 MW thermal (350 MWe net). With respect to current technology, it is larger than the FFTF (400 MW thermal) now under construction and would serve as a necessary transition towards commercial size plants (e.g., 1,000 megawatts electric and above). Information gathered and experience gained throughout the design, construction, and initial operation of the CRBR would be factored into the design, construction and operation of the larger Near-Commercial Breeder Reactor (NCBR). The NCBR is expected to be a large, commercial-size power plant (in the 1000 to 1500 MWe range) which would provide large scale LMFBR plant experience. Proponents of the program have stressed the importance of maintaining the momentum of the

government-industry team now committed to the CRBR and directed toward producing a product that is economically feasible and otherwise attractive to the electric utility companies—the ultimate users.

Project Background

In 1969, after review of a proposal by the Executive Branch, the Congress provided the statutory authority for the design, construction and operation of a LMFBR demonstration plant. It was intended that this plant would be built as a cooperative undertaking among the Federal government, industrial contractors and the electric utilities. The project was to be carried out in two phases. The first phase, project definition, provided the vehicle for potential industrial participants to define the technical and economic characteristics of the proposed undertaking. The second phase of the project involving detailed design, construction and operation, crystalized in January 1972, when the Atomic Energy Commission accepted a joint proposal of Commonwealth Edison Company and the Tennessee Valley Authority as the basis for a government-utility arrangement. Subsequently, the Project Management Corporation and the Breeder Reactor Corporation were formed to represent the utility participants. The Breeder Reactor Corporation was established for the purpose of obtaining financial contributions from the electric utility industry and toprovide information exchange between the major participants and the utility organiza ions. The Project Management Corporation was established to carry out the overall management of the project and to specifically direct work on the "balance of plant."

Proposals were solicited in March 1972 from reactor manufacturers and qualified architect-engineering firms. In November 1972, Westinghouse was named as the lead reactor manufacturer with Atomics International and General Electric as supporting manufacturers. Burns and Roe was selected in December 1972 as the architect-engineer.

A memorandum of understanding among the parties was signed in August of 1972 and amended in January of 1973. Contracts among the parties (AEC, PMC, TVA, CE, and BRC) were signed in July of 1973. Project Management Corporation signed a contract with Westinghouse, the lead reactor manufacturer, in November of 1973 and another with Burns and Roe, the architect-engineering firm, in January 1974.

In October 1974, the environmental report and application for license were submitted to the regulatory staff of the AEC. (These items are now under review by the NRC.)

In March of 1975, ERDA informed the Joint Committee of its intention to make major changes in the management structure for the Clinch River Project. The stated purpose of the proposed changes is to structure the project into a single, integrated Government-utility staffed organization, with the capability to utilize all project resources, including both Government and industry personnel, facilities and funds. This was deemed appropriate by the principal participants in the project in recognition of the Government's increased financial commitments necessitated by the revised estimate of project costs.

Schedule

The current schedule for CRBR calls for completion of construction and achieving of initial criticality by the Fall of 1983. This schedule presumes receipt of a limited work authorization in the Summer of 1977. Pouring of concrete would begin early in 1978. The reactor vessel would be set in place in the Spring of 1980. The testing of sodium systems would commence during the Fall of 1982 and receipt of an operating license from NRC would be expected in the early part of 1983. Detailed design and procurement of all components and sub-systems would, of course, be carried out in such fashion so as to meet the construction and licensing schedule described above.

Oral testimony received throughout the hearings and questioning of witnesses by the Subcommittee brought out that there was a general consensus that research and development on the breeder reactor should be pursued at this time. It became evident that the differences of opinion among witnesses centered on whether the design and timing (schedule) for CRBR are optimal. One of these witnesses, Dr. Rose of MIT, expressed his view as follows:

> The point I want to make most explicitly is that we should study what kind of breeder we need because it is such an expensive undertaking and there is so much at stake in the future. We want to build the best breeder we can which means we want to develop the best breeder we can or the best set of breeders, if that is the proper decision.
>
> Consequently, the Number 1 thing that I would urge is a study of what kind of breeder we should have and whether our program is going in the right direction, a continual re-study, and that is irrespective of whether we build the Clinch River plant or not.
>
> I happen to believe that if we study it, we will come out with a better breeder and that it would pay us to wait, but that is less sure than I am quite sure that we need the study.

As will be commented upon later in this report, the proponents of the CRBR advanced compelling arguments to the effect that it would be unwise to delay the project for the purpose of making major changes in design. Some portions of the facility will not be committed to final design until later in the design and construction effort and some updating may well be achieved in order to take full advantage of current technology.

Propriety of Size Selected

The Clinch River Breeder Reactor has been sized at 350 megawatts electric (net). From the standpoint of thermal rating, it is about two and one-half times the size of the FFTF and would be about one-third to one-fourth the size of the Near-Commercial Breeder Reactor plant. The size selected for the CRBR was chosen to provide some extrapolation from our current technology base and at the same time provide a reasonable step to the Near-Commercial Breeder Reactor.

Design and manufacturing experience from the FFTF—particularly in the large component area—is expected to contribute significantly towards the design and construction of the CRBR.

Relationship of CRBR to FFTF

It should be recognized that the FFTF is intended for the irradiation and testing of fast breeder reactor fuels, materials and components. There are some features of commonality between the CRBR and the FFTF. Experience gained in the design and construction of the FFTF is to be utilized in the design and construction of the CRBR. The FFTF produces no electricity, while the CRBR is intended to demonstrate the production of electricity by a breeder reactor with high availability on a utility grid.

Some witnesses before the Committee felt that the CRBR should be delayed at least until the FFTF becomes operational. This scheduling in their view would permit efficient utilization of experience and knowledge gained from the FFTF for use in the CRBR. Proponents of the ERDA program disagree. They point out that the "in-series" conduct of such projects actually results in less efficient utilization of experience in that design teams cannot be held together in the interim period (later stages of construction and early period of operation) and manufacturing skills and techniques are lost in between jobs.

Relation of CRBR to NCBR

The Near-Commercial Breeder Reactor (NCBR), whose schedule for design and construction would follow the CRBR by about 4 years, would be a large-scale, commercial size LMFBR operating at about three to four times the power level of CRBR. ERDA expects that the NCBR will be a cooperative project between the Government and industry.

ERDA's program plan calls for the commencement of NCBR detailed design and construction prior to the time the CRBR would become operational. This is another case where some respondents and some witnesses urged that the projects be carried out in-series rather than on overlapping schedules. This argument was made on the basis of the contention that an in-series program would permit maximum utilization of information gained from a preceding step to a succeeding step. The proponents of the program advanced arguments similar to those used in connection with the FFTF–CRBR schedules, namely that we must move ahead with the technology and our construction of demonstration projects as rapidly as we are capable of pursuing them in order that commercialization can occur in the mid-1990's rather than at some later date. If each and every step of our technology development and construction program were carried out in-series, the resultant stretchout of the program would significantly postpone the time that a decision respecting commercialization of the breeder could be made.

Industry representatives hold that parallel development or overlap in complex development projects of similar nature is highly desirable and, in fact, in the long term, cheaper than sequential development. They observe that design teams, manufacturing skills and specialized manufacturing techniques are lost in the stop-start approach inherent in sequential development.

Alternative Program

Some respondents and some witnesses recommended strongly that the LMFBR program be delayed by at least a decade. They would prefer to see the program centered on the FFTF, and the CRBR cancelled. The savings in overall costs of the program would, in their view, permit accelerated development of non-fission technologies. Further, the additional time prior to actual demonstration would permit further study and assessment of questions pertaining to LMFBR safety, plutonium risk, and safeguards.

Proponents agreed that portions of the Clinch River design could be improved in accordance with our present knowledge and redesign would result in some improvement. However, it was estimated that about half the systems in Clinch River are fundamental to any liquid sodium plant and would provide a direct stepping stone to the NCBR. A redesign was said to require three to five years and it was observed that when the redesign was completed it would be obsolete with respect to the then-current technology. It was further pointed out that this is generally true for other major technical development programs.

Proponents of the current LMFBR program warned against delaying the CRBR. They pointed out that the design team once dispersed, could not be readily reconstituted, costs of the project would escalate, and such action would probably eventually eliminate the nuclear industry as a viable industry in this country.

Another possible program alternative discussed before the Subcommittee was the use of foreign breeder technology. It was observed that the French, in July of this year, completed the first year of operation of their demonstration plant, the 250 megawatt Phenix reactor, at a high load factor. The British and Russians have demonstration projects constructed and in operation. It appeared logical to some that we should cut back substantially on our own development and demonstration programs and at the appropriate time buy breeder reactors of foreign design. As discussed in section III. E., others felt strongly that the development of the breeder as an energy option was too important a matter to be left to other countries and that our own program should be accelerated in order to establish the U.S. position in this coming world market.

Costs

In the Summer of 1972 the AEC furnished to the Joint Committee a Program Justification Data Arrangement (No. 72–106) identifying the participating parties, the prime contractual relationships among the parties, a description of the proposed demonstration project, a projected cost estimate and other general information. Plant costs were estimated at $496 million, net cost of operations at $44 million, and escalation at $159 million, for a total estimated project cost of $699 million. Project resources were estimated to range from $696 to $716 million, including $254 million in the form of contributions from utilities.

On March 10, 1975, ERDA submitted to the JCAE a revised program justification data arrangement indicating a substantial increase in the estimated cost of the project as follows:

	Millions of dollars
Plant investment	855
Development	327
Net operating costs	58
Escalation [1]	496
Total	1,736

[1] Based on an average annual rate of 8 percent; estimate in 1974 dollars.

It became apparent that if the project were to go forward it would be necessary for the Government to furnish the necessary additional funding. (Utility contributions remained essentially the same as before, $258 million.)

ERDA attributes the increase in cost from the earlier 1972 estimate to the current estimate to be primarily the result of a better definition of project scope, including design changes, the effects of inflation, cost trends in the utility supply and manufacturing industry, and increased environmental and licensing constraints.

The Congress, in its action on the authorization legislation for ERDA for fiscal year 1976 and the transition quarter, approved authorization of $110.3 million for the Clinch River Breeder Reactor. There is specific provision in the revised statute for annual review of the total Government assistance to the project through the annual budget review process.

Dr. Hans Bethe, in his testimony before the Subcommittee, presented an examination of the "high" costs of the CRBR as follows:

With respect to the current estimate of $1.736 billion, it is noted that about one-half that amount is attributable to the actual building of the plant and providing the first load of fuel, a large portion goes into the development and testing of components, a small amount into operating the reactor for five years, and $500 million is the estimated inflation escalation. The cost per installed kilowatt for the CRBR works out to be $2400. This can be compared to $350 per installed kilowatt (without escalation and interest) for a present day light water plant. Dr. Bethe pointed out, however, that CRBR is a "first of a kind", it is overdesigned, and many of its components would remain virtually unchanged in scale-up from the 350 megawatt CRBR to a 1500 megawatt commercial plant. He cited the experience of the pressurized water reactor (PWR)—a ten-fold increase in power from the prototype (Shippingport) to present plants with only modest increase in the amount of materials (concrete, piping, cables, etc.). He concluded that the cost per kilowatt for the final breeder reactor will only be 50 percent more expensive than for a light water reactor and notes that the real payoff results from the fuel expense which would be considerably lower for the breeder than for the LWR (100 times lower for uranium priced at $150 per pound).

Conclusions

The Subcommittee emphasizes that the CRBR is an important and necessary element in the orderly progression of research, development and demonstration for a responsible LMFBR program. The Subcommittee also believes that the projected operational schedules of the FFTF and the CRBR project permit a proper use of design experience and allow for an efficient utilization of scientific and engineering manpower.

Recommendations

The Subcommittee recommends that the ERDA and its industry partners in the CRBR project make every reasonable attempt to adhere to the present schedule for design, construction and licensing review of the CRBR. If any future turn of events indicates to the project participants an opportunity for improvement in the schedule for the CRBR's availability date, the matter should be pursued and the Joint Committee so notified.

G. SAFETY AND ENVIRONMENTAL CONCERNS

Among the concerns expressed by opponents to nuclear power, safety and environmental issues have been the most emotional. Sensational headlines and stories in newspapers or magazines and exaggerated statements in various town meetings or public debates have aroused fear in certain sectors of the public, many of whom still associate anything nuclear with the atomic bomb. Safety and environmental concerns were therefore examined at some length by the Subcommittee. Discussed below are the four major concerns on which considerable discussion is taking place: reactor safety, management of reactor wastes, nuclear safeguards, and plutonium toxicity. This Subcommittee encourages continued public review and debate on these issues. It would be most beneficial for the government and the nuclear industry to increase their efforts to educate the public about nuclear power, both its benefits and risks. We believe critics of the nuclear program also play an important role when they present their arguments on these issues in a responsible manner. The press can also perform an important function by presenting a balanced and objective treatment of these subjects.

An additional item, the environmental aspects of coal production and use, was addressed during the Subcommittee's review and some comparison of the potential environmental effects between the use of coal and uranium/plutonium was covered. This is discussed in Section III. G. 5. In addition, the concept of energy centers is addressed in Section III. G. 6.

1. Reactor Safety

Conclusions

Reactor safety questions noted during the Subcommittee's study appear amenable to technical resolution. The Subcommittee notes with satisfaction that a comprehensive research program is being carried forward to assure that ever conceivable hazardous circumstance or condition that might arise in a Liquid Metal Fast Breeder

Reactor is being considered in advance, and that no credible situation or accident has been hypothesized to date for which adequate design and safety features are not under consideration.

PRIMARY SAFETY ISSUES

The primary safety issues relative to breeder reactors that were identified to the Subcommittee were the likelihood and potential consequences of a major nuclear accident. A key item in assessing the likelihood of a major accident is the performance of the reactor's plant protection system, whose primary function is to shut the reactor down whenever there are indications of off-normal behavior and to keep the reactor in a safe shutdown condition. Proponents of nuclear power argue that the overall plant protection system (of which two independent, redundant and diverse reactor shutdown systems are a major part) is sufficiently reliable to prevent extremely serious accidents from occurring. If the reliability of the plant protection system can be demonstrated to be sufficiently high, proponents argue, postulated events involving simultaneous failure of the two shutdown systems and the resulting consequences need not be a part of the reactor design basis, since the likelihood of an accident occurring will be so low. The other side of the argument is that demonstration of such high reliability (e.g., one chance of a fault in a million) cannot be shown. Items such as common mode failures or human error, it is argued, cannot be satisfactorily factored into an analytical assessment of the reliability of the system and, therefore, the consequences of a postulated event with failure of protection systems must be specifically addressed in the design.

POTENTIAL CONSEQUENCES

The second major point hinges around the potential consequences of such accidents, which are considered to be extremely low in probability. Nuclear power proponents point out that even if core meltdown events [1] are not part of their design bases, there are many inherent features in the design and construction of breeder reactors such that a wide range of consequences from these extremely low probability events can be accommodated without harm to the public. This capability is contained in items such as a thick reactor vessel head, the inherent strength of the piping and vessels comprising the primary coolant system, an inerted reactor cell capable of standing high pressures (e.g., 35 psi) and, ultimately, the outer containment building itself. Other groups such as the Nuclear Regulatory Commission have not concluded yet whether breeder reactor designs should be based on these extremely unlikely meltdown events. Opponents to nuclear power state that the consequences from such a reactor core meltdown accident would be so large and severe that the overall containment system integrity cannot be assured. Dr. Thomas Cochran

[1] A core meltdown event comes from the assumption that for some reason power is lost to the pumps, the coolant flow through the core subsides and the plant protection system, which has specifically been designed to protect the reactor from such an event, does not function. With such assumptions, heat removal from the core would not keep up with the heat generation with the result that the core would overheat. If this condition persists long enough, the core could begin to melt with the potential for a release of energy.

of NRDC, in "Bypassing the Breeder," March 1975, puts it the following way:

> In the event of a meltdown, the breeder's high enriched fuel can rearrange itself to a more compact configuration with possibility of small nuclear explosions [2] of sufficient force to breach the reactor containment.

Industry and government spokesmen state, however, that claims such as Dr. Cochran's are overstatements of the facts. The proponents point out that none of the experimental evidence developed to date indicates that such large energy releases can occur and, in fact, the release of energy from small scale molten fuel-coolant interaction experiments has been quite benign. Only when parametric studies are carried out using very pessimistic assumptions do larger energy releases appear. Even for a large number of these parametric cases, proponents argue, the consequences would be contained essentially within the primary cooling boundary, which itself is located inside the containment.

Considerable research and development by industry and the government on the likelihood and potential consequences of a major reactor accident is ongoing. Congress has continued to fund safety programs addressing these questions. To this Subcommittee, it appears that the safety problems noted are amenable to technical resolution and that an appropriate R. & D. program is underway which has every evidence of eventual success. The Subcommittee does not believe there is sufficient basis for the contention of some critics that the demonstration plant phase of the LMFBR program should be delayed while more fundamental safety R. & D. takes place. Continued safety R. & D. should proceed as an integral part of the demonstration plant program.

The need to continue safety R. & D. and demonstration plant construction simultaneously is a conclusion which appears consistent with those reached by foreign countries as well. As noted earlier, this Subcommittee recently visited several Western European countries with breeder development programs of their own. In each country, the Subcommittee was told that the consequence of major nuclear accidents was recognized and that they believed such accidents were capable of being dealt with. This fact is made even more pointed when one recognizes that countries such as France and the United Kingdom have already completed demonstration plants comparable to our CRBR, and have begun design and R. & D. on commercial-sized prototype plants.

Postulated core disruptive accidents are not the only events under the heading of reactor safety. Other concerns were noted to the Subcommittee, such as steam generator leaks or sodium fires. R. & D. in these other areas is also underway. These potential accidents, while important, are not considered by supporters or critics of the breeder to be as significant in their potential public impact as the postulated core disruptive event, and therefore these other safety issues are only mentioned in this report in passing. Certainly this Subcommittee urges continuing investigation in all areas of reactor safety.

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[2] By a small nuclear explosion, Dr. Cochran does not mean that on the order of an atomic bomb, but rather a much smaller release of energy that could vaporize some of the core fuel (see House of Representatives Publication Serial No. 94–16, Part 1, Page 656).

Conclusions

Reactor safety questions noted during the Subcommittee's study appear amenable to technical resolution. The Subcommittee notes with satisfaction that a comprehensive research program is being carried forward to assure that every conceivable hazardous circumstance or condition that might arise in a Liquid Metal Fast Breeder Reactor is being considered in advance, and that no credible situation or accident has been hypothesized to date for which adequate design and safety features are not under consideration.

Recommendations

The Subcommittee recommends that the ERDA, NRC, reactor vendors and utilities continue to give close attention to the development of safe breeder reactor designs and carry out the necessary experimental programs to substantiate all important elements of those designs.

2. Waste Management

Conclusions

The Subcommittee concludes that, on the whole, the potential difficulties which may be encountered in the radioactive waste management program do not pose risks to the public of such magnitude that this Nation should forego its nuclear energy program, including the development of a breeder reactor. Clearly much remains to be done to demonstrate and finalize the technology for long-term waste management, but the problems involved are not insurmountable.

DILEMMA RESULTING FROM CONFLICTING VIEWS

Uncertainty with respect to the management of radioactive wastes from nuclear fission was suggested to the Subcommittee as one reason to go slow or stop work on the breeder program. Some scientists assert that the hazards from deliberate or accidental or eventual release of these wastes into the environment is too high a price for society to pay for the benefits from nuclear power. Other scientists and engineers assert that techniques for management of wastes and the prevention of inadvertent release are almost in hand and that the probable risks of release are so small that the benefits of nuclear power far outweigh them. The Subcommittee, the Congress and the public at large face the classic dilemma of receiving conflicting analyses and advice from opposing experts. A brief review of the opposing opinions presented to the Subcommittee follows.

SUGGESTED METHODS

Concern over waste management and the breeder was most powerfully presented by the Natural Resources Defense Council in its comments on the draft environmental impact statement for the breeder.

> . . . Clearly, the storage of high-level radioactive wastes poses new problems of a very high order for the society as a whole. Simply, technological solutions do not exist. High-

level radioactive waste management is a multi-faceted, socio-technological problem. Wise social judgment is needed for a solution, in addition to the application of good science.

The NRDC holds that there is no evidence that in the near future a generally accepted means for safety storing or disposing of the high level radioactive wastes will be developed.

On the other hand, NRDC sees possibilities in some options for future waste management, calling attention to the ideas of separating the long-lived transuranic wastes and transmuting them into radionuclides of shorter lifetimes. This option would greatly shorten the time the remaining wastes would have to be stored.

Professors Rose of MIT, Wilson of Harvard and Cohen of the University of Pittsburgh are among those who have addressed the issue of nuclear waste. Professor Rose summarizes succinctly:

> In general, I think the nuclear waste problem has been both over-emphasized by the critics and mis-assessed by the U.S. AEC and its contractees, who failed to recognize many implicit societal issues.

Professor Rose agrees with the general conclusion that the best route is solidification of wastes with subsequent shipment to and disposal in salt deposits. He pointed out to the Subcommittee that there are other schemes which deserve serious study, including the removal of transuranic elements (as mentioned above) which can then be recycled in a reactor designed to burn them up. Storage of the fission products in granitic rocks was mentioned as another possibility.

Professor Wilson of Harvard calculates that if all but 0.5 percent of the plutonium in reactor spent fuel were to be removed, an amount believed to be technically achievable, then after 500 years the waste would be no more radioactive than pitchblende in nature. If all but 0.01 percent of the plutonium and transuranic elements were removed, the waste at that time would be no more radioactive than granite rock.

Professor Cohen of the University of Pittsburgh reported a general agreement among knowledgeable scientists that intensely radioactive wastes will eventually be buried deep underground in some carefully chosen geological formation. As for the burden upon future generations, he estimates that even without a guard force to keep people from digging up the wastes, the possible death toll from escape of material which is simply buried at 2000 feet below the surface in random locations throughout the United States would have an upper limit of 4 deaths per decade. He stated that a waste disposal site would require perhaps one person to routinely travel around a site of 200 square miles to monitor and police. In Professor Cohen's view, the accelerated use of coal, oil and natural gas would place a far more onerous burden on future generations than the storage of radioactive wastes:

> When one considers the burdens we are placing on future generations, the added radiation exposure which will be given them through our wastes is surely very unimportant it will increase their exposure over that from natural resources by only about one part in ten billion for each year of all-nuclear power.

In addition to the controversy over waste management, a related matter of which the Subcommittee is aware concerns the absence of an industrial base and capability for processing and storage of high

level nuclear wastes. If such a capability is not created soon, within a few years the users of light water reactors will face the choice of providing new or expanded facilities for holding used spent nuclear fuel, or shutting down powerplants as fuel storage facilities are filled up. The absence of such an industrial capacity appears far more the result of an ideological impasse rather than lack of promising technological options. This impasse results in part from the implicit assumption of the AEC, and now ERDA, that today's nuclear industry has or can get the resources to do whatever is needed to create a commercial waste management service. ERDA's programs for waste management continue to lag behind earlier schedules intended to provide timely solutions to the long term storage and/or disposal problem. Additionally, the Nuclear Regulatory Commission must establish necessary licensing criteria so that industry can move ahead in this area. The future contribution of nuclear power to the Nation's economy and defense is far too important to be made the hostage because of lack of agreement among ERDA, NRC and private enterprise. As with every other source of energy that we hope to get out of laboratories and into use, creating the industrial bases for these new technologies demands a vigorous, coordinated effort by all sectors working together.

The Subcommittee notes that in a recently published National Academy of Sciences report their Committee on Radioactive Waste Management has endorsed conclusions and recommendations arrived at by its Panel on Engineered Storage following an analysis of concepts proposed by the AEC for retrievable surface storage of solidified high-level radioactive wastes. Included therein was the Panel's conclusion that "retrievable surface storage is an acceptable interim stage in a comprehensive system for managing high level radioactive wastes".

For long-term waste management, the crying need is to get moving and to forget past preoccupation with doctrinary issues whose timeliness is fading fast in today's world of competition for dwindling fossil fuels.

In summary, development and commercial use of the breeder will require both demonstrated technology and an industrial base for high level radioactive waste disposal. That technology and base is also required to meet near-term needs of the light water reactors. Technologies are now close at hand for long-term storage of these wastes. New options have to emerge to reduce the future long-term problems of waste management and these should be vigorously pursued by ERCA and the industry, including separation of transuranic wastes and their subsequent transformation in fission or fusion reactors; and separation of cesium and strontium from fission products for use as sources of energy.

Conclusions

The Subcommittee concludes that, on the whole, the potential difficulties which may be encountered in the radioactive waste management program do not pose risks to the public of such magnitude that this Nation should forego its nuclear energy program, including the development of a breeder reactor. Clearly much remains to be done to demonstrate and finalize the technology for long-term waste management, but the problems involved are not insurmountable.

Recommendations

1. In view of the fact that radioactive waste management requirements for breeder reactors will be essentially similar to those for light water reactors, the Subcommittee recommends that the ERDA vigorously pursue its research, development, and demonstration program for waste management and storage. In making this recommendation, the Subcommittee recognizes that the technology required for waste management is largely in hand and that the critical delays being experienced today are primarily administrative and regulatory. Public understanding of the nuclear energy program and the closing of the fuel cycle including waste management are critically important factors which must be addressed at once.

2. The Nuclear Regulatory Commission should maintain close cognizance of waste management research, development, and demonstration programs and provide, in timely fashion for the use of the nuclear industry, approved criteria intended to guide the users and the public as to the acceptability, from a public health and safety viewpoint, of the proposed methods of waste storage and disposal.

3. Safeguards

Conclusions

The Subcommittee concludes that:

1. The chances of successful diversion of a significant quantity of plutonium from the nuclear fuel cycle by an individual or small group for terrorist purposes are extremely small.

2. There can be no absolute guarantee against theft of nuclear materials by a well-organized and equipped group willing to accept casualties and possible radiological injury incurred by inadequate handling of these materials.

3. Because of the potential consequences of diversion of nuclear materials for clandestine purposes safeguards systems must be devised and implemented in a manner which will minimize the possibility of success of such an undertaking.

4. The suggestion that the imposition of appropriate safeguards measures for the nuclear fuel cycle threatens the civil liberties of the people of this or any other country does not appear warranted.

Of all the issues raised about nuclear power and the breeder, the issue of nuclear safeguards—the protection of nuclear materials and facilities against diversion, theft or sabotage—is probably the most subjective. Assessment of these risks and the effectiveness of technological and other measures to control them depends upon assumptions about human behavior, on which, understandably, there are many conflicting views. Concern about safeguards was most recently expressed in the declaration of the Union of Concerned Scientists of August 6, 1975, to the President. According to this declaration:

> The connection between commercial nuclear power plants and nuclear explosives is another legitimate source of concern. Various studies carried out by the Government, as well as by outside reviewers, point up multiple weaknesses in safeguards procedures intended to prevent theft or diversion of commercial reactor-produced plutonium for use in illicit nuclear explosives or radiological terror weapons. Proposals for satisfactory plutonium safeguards procedures appear to

> require special pervasive security apparatus incompatible with American traditions of freedom, an apparatus which could take the United States a long way down the road to a police state.

In contrast to that view, the Subcommittee heard testimony from responsible scientists and engineers that indicated a consensus that safeguards, while certainly requiring improvements to meet future needs of an expanding nuclear industry, can be sufficiently effective to permit projected commercialization of the breeder reactor.

POINTS FOCUSED UPON

The Subcommittee has given careful consideration to the issues raised and to claims and counterclaims. Some of the points the Subcommittee focused upon concerning safeguards included the following:

Goals for safeguards.—ERDA, in its Proposed Final Environmental Statement on the LMFBR, stated that safeguards are designed to deter, prevent, or respond to (1) the unauthorized possession or use of significant quantities of nuclear materials through theft or diversion and (2) sabotage of nuclear facilities. Safeguard measures have as their objective achieving a level of protection against such acts sufficient to insure against significant increase in the overall risk of death, injury or property damage to the public from cause beyond the control of the individual. This ERDA statement was criticized in comments on the PFES for its lack of quantification. Most recently, the ERDA Administrator's Internal Review Board on the PFES noted that testimony at ERDA's public hearing on the statement indicated that a zero risk safeguards system is not considered feasible, but that the goal of safeguards to reduce risk to the absolute minimum is achievable. As the Board sees it, more precise definition of safeguards risks and goals is certainly relevant to the acceptability of an LMFBR economy. Moreover, further research and development into safeguards concepts and technologies is a prerequisite for setting standards of performance. "Social choices should be made on the basis of a reasonably precise quantification of the risks to be incurred rather than upon a necessarily imprecise projection of the degree deemed attainable in advance." Additionally, the Board observed that statement of objectives or standards of performance for safeguards are rather meaningless until the results of such research become available.

Costs of safeguards.—The capital and operating costs of a stringent safeguards system for a breeder economy have been estimated to be large, perhaps $100 million a year for 80 breeders, but the effect on the cost of power generated would be small. According to analysis by one witness before the Subcommittee, safeguards costs would add only 1.4 percent to the cost of electricity assuming a cost of 13 mills per kilowatt hour. Another knowledgeable witness estimated that financial costs of safeguards would not have significant effects on the overall LMFBR cost-benefit balance. Even with a conservative approach, capital costs for safeguards are estimated at less than 1 percent of total capital costs and operating costs at less than 2 percent of the cost of power. Granted that both these estimates are preliminary they do indicate that the costs of safeguards should not prove to be an insurmountable economic barrier to the breeder.

Ease of bomb making.—The public has been deluged with films and articles about the presumed ease of making bombs from stolen nuclear

materials. Dr. Taylor in his testimony advised that with about 10 kilograms of reactor grade plutonium oxide or about 20 kilograms of highly enriched uranium oxide, and using available information and supplies, it is quite conceivable that a criminal or terrorist group, or one person working alone, could design and build a crude fission bomb that could be carried in a small automobile and that would be likely to explode with a yield equivalent to at least 100 tons of high explosive. He estimated that in a densely populated city such an explosion could kill more than 100,000 people. On the other hand, ERDA holds to the view that fabrication and assembly of a workable weapon is complex and laden with many obstacles, any one of which could prevent success. The Proposed Final Environmental Statement on the LMFBR contains the following:

> The attempted detonation of even high-grade material is more likely to result in a low tonnage yield or a disassembling, non-nuclear explosion than a substantial yield explosion unless the fabrication and assembly have been carried out by highly trained and experienced technicians.

A weapon made directly from LMFBR fuel-cycle material would be less likely to operate satisfactorily. Thus, ERDA rates the overall probability of any successful explosion of an illicit weapon as extremely low.

Nonetheless, the design and implementation of safeguards rests on the premise that making an illicit nuclear explosive is within the range of skills and resources available to persons or groups operating outside the law. ERDA agrees that if a workable illicit device of even modest yield were cleverly placed and set off, thousands of people could be killed and millions of dollars of property destroyed.

Research and development for safeguards.—Nuclear safeguards are still in their infancy and have a long way to go as the nuclear industry grows. Improvements in safeguards technologies are needed. The ERDA safeguards research program will require continued priority and support. Further, the expanding NRC safeguards program should be closely coordinated with that of ERDA. Since the United States does not have a world corner on ideas for effective safeguards, ERDA and NRC both should actively explore possibilities for collaboration with foreign safeguards organizations and with the International Atomic Energy Agency.

The human element and zero risk.—The Oak Ridge National Laboratory in its reply to the Subcommittee questionnaire identified personal reliability as the most important single element in any system to protect plutonium. ERDA's review board observed that safeguards systems will remain basically human institutions subject to inherently human failings. "It is not apparent that a technological approach to the safeguards problem can entirely obviate errors in judgment or venality on the part of the nonmechanistic, human component of the safeguards problem." Opponents of the breeder hold that because of this human component, the meaningful quantification of risk will forever remain beyond the state of the predictive art. Therefore, they conclude it will never be possible to determine the true extent of the risk, or to judge its acceptability. Considering the importance of the human element, it is surprising that much of ERDA's research and development program concentrates upon hardware to the virtual exclusion of the human element. It appears self evident that ERDA

and NRC in planning their research and development programs, should include further analysis of the human component of safeguards. To avoid duplication, the Subcommittee hopes these agencies will work closely with the Department of Defense, and that the latter will assist by making available results of analyses and experience dealing with the human element in military operations involving nuclear weapons.

Conclusions

The Subcommittee concludes that:

1. The chances of successful diversion of a significant quantity of plutonium from the nuclear fuel cycle by an individual or small group for terrorist purposes are extremely small.

2. There can be no absolute guarantee against theft of nuclear materials by a well-organized and equipped group willing to accept casualties and possible radiological injury incurred by inadequate handling of these materials.

3. Because of the potential consequences of diversion of nuclear materials for clandestine purposes safeguards systems must be devised and implemented in a manner which will minimize the possibility of success of such an undertaking.

4. The suggestion that the imposition of appropriate safeguards measures for the nuclear fuel cycle threatens the civil liberties of the people of this or any other country does not appear warranted.

Recommendations

The Subcommittee recommends that the ERDA and the NRC work closely together to define precisely safeguards risks and the goals to be accomplished in order to ensure the security of nuclear materials. In so doing, the ERDA and the NRC should make maximum use of the expertise and knowledge resident in sister Federal agencies.

(For a view of the manner in which the development of energy centers can contribute to the minimizing of safeguards risks, the reader is referred to section III G. 6, p. 91.)

4. Plutonium Toxicity

Conclusions

The Subcommittee finds that:

1. Since its discovery more than three decades ago, countless man years of diligent research work have been brought to bear on the subject of plutonium toxicity, both in this country and throughout the world. It is well recognized that carcinogenic properties of inhaled plutonium require that the high standards of care in the handling of this material which have been traditionally practiced for the past 30 years must be maintained.

2. The capability of inhaled plutonium within a specific particle size range to produce lung cancer has been demonstrated in experimental animals. There are no cases on record of human lung cancer attributed to exposure to plutonium notwithstanding the fact that a number of early workers in the U.S. military program were accidentally subjected to lung doses significantly above levels prescribed in radiation protection guides.

3. Approximately five tons of plutonium-239 have been injected into the atmosphere primarily in the Northern Hemisphere by atmos-

pheric weapons testing. About four tons of this have fallen to the surface of the earth. Every human being in the Northern Hemisphere is carrying a measurable amount of this plutonium in his body. Although these atmospheric weapons tests occurred more than a decade ago, there is no indication that this plutonium deposition has caused any untoward health effects.

4. The theory that plutonium would be extraordinarily dangerous in the form of "hot particles" in the lungs has been thoroughly analyzed by competent and independent scientific bodies both in Great Britain and the United States and found to have no substance in scientific fact.

The hazards of potential plutonium releases were suggested by several witnesses and by persons providing written statements for the record as a major reason for not pursuing the LMFBR. The general argument set forth was that plutonium was so toxic and capable of producing large number of cancers or other somatic effects that it should not be produced in large quantities and used as fuel in power plants, since the escape of even small quantities could have disastrous consequences. An example of a common statement made regarding the consequence of plutonium release is "one kilogram (of plutonium) is 9 billion cases of lung cancer."[1] Medical researchers in this field point out, however, that actual experience does not bear this out. They point out as an example the fact that over five tons of plutonium have been dispersed in the atmosphere by nuclear weapons tests. Using the conversion factor of 1 kg=9 billion cancers would mean each person on earth would have already received many body burdens (maximum allowable amounts) of plutonium. In testimony before this Subcommittee, Dr. Chet Richmond of the Oak Ridge National Laboratory, stated that "It has been estimated that little (one part in 100 million)," of the plutonium from the weapons tests, "has found its way into the earth's population and that the average accumulation per person is about one part in 10^{17} of that released." The overstatement or seeming scare tactics regarding the hazard of plutonium are commonly used by some critics and is of increasing concern to this Subcommittee.

Written information and prepared testimony also provided a comparison of the toxicity of plutonium to other substances. These comparisons are often made in counter to statements by some, for example, that "plutonium is probably the most dangerous substance known."[2] Items noted to this Subcommittee as being more toxic than plutonium are botulinus toxin A, serium hepatitus virus, potassium cyanide and parathion. The thrust of these arguments was not, however, to allow reduction in the care that is needed in handling plutonium. Rather, these comparisons indicate that plutonium is indeed quite toxic but not out of proportion to other substances with which we are familiar. on April 22, 1975 summarized this as follows: "So while plutonium is unquestionably very toxic, it is not the most toxic substance known to man, so it is not drastically different from other materials accepted in our society."

Industry and government witnesses were in agreement with the critics that plutonium is quite toxic and it was for this reason, they stated, that so much care was taken to assure that potential releases of plutonium were reduced to acceptably low levels. Plutonium han-

[1] Speech by Ralph Nader, March 3, 1975, to Lafayette University.
[2] T. Cochran, "Bypassing the Breeder," March 1975.

dling operations at many locations throughout the country were cited as examples where successful programs had taken place for greater than 20 years.

HOT PARTICLE HYPOTHESIS

A specific issue in regard to plutonium has been reported to the Subcommittee by the Natural Resources Defense Council (NRDC). This is the so-called "hot particle" problem. Basically, the hot particle hypothesis states that the damage potential to tissues is much greater when isolated plutonium particles intensely irradiate very small volumes of adjacent tissue rather than if the same activity of radiation were uniformly absorbed throughout the organ of interest, e.g., the lung. Based on this hypothesis, NRDC's referenced testimony to this Subcommittee was that a reduction of 115,000 in the allowable plutonium dose limit should be made. This issue has received considerable attention by research groups both in this country and abroad. The overwhelming conclusion reached from these studies has been that the present methods of analysis are satisfactory and that a reduction by 115,000 in the allowable dose limit is not justified. In testimony to this committee, Dr. Chet Richmond quoted the following from a United Kingdom Medical Research Council Committee report entitled "The Toxicity of Plutonium" (Medical Research Council, 1975):

> "For many years, those professionally concerned with radiological protection have been aware of the need to establish general principles for assessing the relative risks of homogeneous and inhomogeneous irradiation. As discussed in the Appendix [to the MRC report], there is no evidence that radiation by 'hot particles' in the lung is markedly more hazardous than the same activity uniformly distributed or that the current recommended standards for inhalation of plutonium are seriously in error."

Other evidence often quoted and which was provided to this Subcommittee deals with the 25 workers at the Los Alamos, N.M. laboratory who accidentally received multiple body burdens of plutonium during the initial years of nuclear research. This group has been followed for almost 30 years and has had no lung cancers from plutonium. Further, the lung burdens to some workers at Rocky Flats were one to ten times the maximum allowable limits. Yet in the past nine years, there has been no detection of lung cancer in any of these individuals.

This Subcommittee, of course, is not expert on the medical effects of plutonium exposure. However, we cannot help but be impressed by the data presented and conclusions reached by group after group of experts in this area, all of which have rejected the hot particle hypothesis. In fact, the question was raised during the hearings concerning whether there was any need for additional studies on the hot particle issue in light of all of the studies and evaluations conducted to date and the consistent conclusion that has been reached.

Conclusions

The Subcommittee finds that:

1. Since its discovery more than three decades ago, countless man years of diligent research work have been brought to bear on the subject of plutonium toxicity, both in this country and throughout the world. It is well recognized that carcinogenic properties of inhaled

plutonium require that the high standards of care in the handling of this material which have been traditionally practiced for the past 30 years must be maintained.

2. The capability of inhaled plutonium within a specific particle size range to produce lung cancer has been demonstrated in experimental animals. There are no cases on record of human lung cancer attributed to exposure to plutonium notwithstanding the fact that a number of early workers in the U.S. military program were accidentally subjected to lung doses significantly above levels prescribed in radiation protection guides.

3. Approximately five tons of plutonium-239 have been injected into the atmosphere primarily in the Northern Hemisphere by atmospheric weapons testing. About four tons of this have fallen to the surface of the earth. Every human being in the Northern Hemisphere is carrying a measurable amount of this plutonium in his body. Although these atmospheric weapons tests occurred more than a decade ago, there is no indication that this plutonium deposition has caused any untoward health effects.

4. The basis for the theory that plutonium would be extraordinarily dangerous in the form of "hot particles" in the lungs has been thoroughly analyzed by competent and independent scientific bodies both in Great Britain and the United States and found to have no substance in scientific fact.

Recommendations

The Subcommittee recommends that:

1. The ERDA in the conduct of its activities and the NRC in its licensing and enforcement actions continue to require the high standards of plutonium protection that have been maintained in the past.

2. The ERDA and other agencies of government concerned with the conduct of health research continue efforts intended to improve our understanding of the biological effects of human and animal exposure to plutonium and other transuranic elements.

5. Environmental Effects of Alternate Energy Sources

Conclusions

The Subcommittee concludes that any alternative energy source is likely to bring with it environmental effects objectionable to some part of our society. Therefore, it would be unwise to assume that alternative energy technologies which have not yet been fully studied will be without environmental impacts of some consequence.

Potential new energy sources are discussed in Section III–C of this report. This subsection summarizes the information received on the environmental aspects of these new energy sources as well as the environmental impact to be expected as a consequence of expanded use of coal as an energy source.

ENVIRONMENTAL IMPACTS IN OTHER ENERGY SOURCES

The alternative posing perhaps the most severe environmental impacts is the expanded use for coal whether for process heat, generation of electricity, or manufacture of synthetic fuels. The manufacture of liquid fuels from oil shales and tar sands were also noted as present-

ing formidable environmental effects. Other alternatives, including geothermal steam, fusion, solar energy, have notable potential environmental impacts and these are summarized in table 1, p. 90.

In its consideration of environmental effects of these alternatives, the Subcommittee came to several conclusions:

(1) Any alternative energy source that is developed and deployed rapidly enough to supply say 5 percent of total U.S. energy input in the year 2000 is likely to bring with it environmental effects that will be objectionable to some portion of our society. Some of these effects can be anticipated. For example, tall wind machines at one mile intervals are just as likely to violate the aesthetic sensibilities of some observers as would a 1,000 foot smoke stack of a coal-fired power plant. Both pose some risk to low-flying aircraft.

(2) Aside from the alternative of coal, these potential environmental effects of energy alternatives are not now widely known to the public. However, experience with siting of dams and reservoirs, oil refineries, and other large energy related installations has shown that there can be a fast response once local groups feel their environment or other interests are threatened by such proposed installations.

(3) Commercial deployment of alternative energy sources will require, as a prerequisite, the full panoply of environmental impact analysis. The National Environmental Policy Act has evolved through court interpretations of cases relating largely to nuclear energy which already have imposed future requirements of environmental impact statements by ERDA on each of its alternative energy programs, and future environmental impact analyses by those Federal agencies that have to issue permits or licenses or take other actions so that energy installation based on these alternatives can be built and operated. At this point the Subcommittee believes it most advisable for ERDA to examine the future requirements for program environmental impact statements and individual environmental impact statements for the various alternatives and to report to Congress and to the public on what environmental analyses will be required, when, and the current state of knowledge about the principal impacts to be considered.

(4) While many, perhaps most of the impacts for energy source alternatives can be identified now, it would be foolish to assume no others will appear as a specific alternative moves through research, development and demonstration to commercial application.

Conclusions

The Subcommittee concludes that any alternative energy source is likely to bring with it environmental effects objectionable to some part of our society. Therefore, it would be unwise to assume that alternative energy technologies which have not yet been fully studied will be without environmental impacts of some consequence.

Recommendations

The Subcommittee recommends that the ERDA and other elements of the Federal Government concerned with potential detrimental public health effects resulting from energy generation and usage continue to pursue, and in some relatively new areas initiate pursuit of, programs which will permit proper assessment of the environmental impact of the generation of energy from all sources and by all mechanisms which may affect the general public.

TABLE 1.—ENVIRONMENTAL EFFECTS OF ALTERNATIVE ENERGY SOURCES

Intensity of effects (descending) and source	Air	Water	Land	Other
1. Coal:				
Mining, deep		Acid mine drainage, suspended solids in mine waste water.	Surface subsidence, mine waste piles.	
Mining, strip	Dust from wind erosion of pits, spoil piles and mine roads.	Silting of nearby rivers from runoff, suspended soilds sometimes exceeding health levels. Some acid mine runoff.	Disturbance of surface, waste piles, unstable waste piles and high walls.	
Processing	Dust	Runoff from waste piles.		
Transport	do			
Combustion	Particulates (fly ash and fines), noxious gases (SO_2, NO_x, CO, CO_2), some radioactive emissions.	Runoff from coal piles and ash piles, chemicals from power plants.		
Synthetic fuels	Combustion products from use, air emissions from production plants.	Water requirements as feed material and for cooling, waste heat dispersal, chemical wates.	Site requirements, solid wastes.	New towns.
2. Oil shale and tar sands.	Dust from transportation and crushing. Process gases. Combustion products from use.	Runoff from spoil banks, disturbance of acquifers, change of watershed runoff, chemical wastes.	Strip mining effects, solid waste disposal restoration effects.	Do.
3. Organic solid wastes.	Combustion products from use.	Waste heat dispersal, chemical wastes, some waste waters high in biochemical oxygen demand (BOD). Runoff from storage piles.	Residual waste disposal.	
4. Peat	Do	Runoff from storage piles, waste heat, chemical wastes.	Disposal of char and ashes.	
5. Geothermal	Release of hydrogen sulfide (H_2S). Release of some radioactive materials.	Impaired quality of surface and ground water at the site, waste heat dispersal, chemical wastes.	Surface subsidence from withdrawal of wafer.	Noise from venting steam.
6. Fusion	Probably routine releases of small amounts of tritium.	Probable release of small amounts of tritium, waste heat, chemical wastes.	Radicactive waste disposal.	
7. Solar energy:				
Direct heating and cooling.	None	None	None	Aesthetic.
Central power	Possible erosion products from collectors.	Waste heat dispersal, chemical wastes.	Large land requirements, 10 to 50 mi^2 per plant.	
Fuel crops	Combustion products from use.	Water requirements for cultivation fertilizer runoff, waste heat, chemical wastes.	Large land requirement.	
8. Wind	Possible alteration of local wind patterns by large number of units.	None	Siting requirements	Aesthetic.
9. Hyrdo	Local weather changes near reservoir.	Reduced oxygen content, increased nitrogen content of water released from dams; silting of dams; changed stream flows down stream.	Land requirements, flooded land.	Aesthetic, changed marine life patterns up and down stream, interference with spawning fish.
10. Tidal	None	Nominal	Impact on wetlands	Changed marine life.
11. Ocean heat	do	Chemical discharges	Sites for shore support.	Obstacles to navigation.
12. Ocean current	do	Nominal	do	Do.

6. Energy Centers

Conclusions

The Subcommittee concludes that:

1. Certain benefits can be reasonably expected to accrue from the establishment of Federally-owned energy centers in various electric distribution regions throughout the country.

2. This concept does not envision requiring that all energy production from nuclear energy or other sources be limited to production from such centers.

3. Energy centers would be ideal centers for development of alternative energy concepts and might prove attractive sites for the production of energy from these sources.

Commercial use of breeder reactors will certainly increase the amounts of plutonium in commerce and industry as the LMFBR come into use and uranium-233 will also be produced if thorium cycle breeders come into commercial use. This situation, as discussed above, increases possible risks of theft of materials or sabotage of facilities. Common sense says that chances of such actions should be kept to a minimum. One approach would be to collect those industrial operations involving fissionable materials and radioactive wastes on one site, or close together in one place, where risks can be reduced through decreased distances of transportation, common physical security and control of routine releases and waste materials, and more effective regulatory control. A site where this is done is called an energy center.

Typically, an energy center could include the so-called front-end operations of the fuel cycle, that is, enrichment if the centrifuge process proves economically competitive for small installations; storage of fissionable materials, and their processing and fabrication into nuclear fuel. Back-end operations could include reprocessing of spent fuel to recover plutonium, uranium-233 and residual enriched uranium; fixation of high level wastes into stable forms; temporary storage of such wastes; and possibly permanent storage in deep geological formations below ground.

The concept of energy centers was supported by several witnesses in their testimony before the Subcommittee. One witness did warn of problems that could occur if some of the participants in the center ran into financial difficulties and were to fail. The possibilities of demonstrating the concept of an energy center by adding certain nuclear operations at the private fuel reprocessing plant now being built at Barnwell, South Carolina, were also reviewed.

The Subcommittee is aware that NRC is working on a nuclear energy center site survey which is required by Section 207 of the Energy Reorganization Act of 1974. NRC's report was due to be submitted to the Congress by October 11, 1975 but has been delayed.[1] It is to include:

1. NRC's evaluation of the results of a national survey to locate and identify possible nuclear energy center sites, and

2. NRC's conclusion and recommendations regarding the feasibility and practicability of locating nuclear power reactors and/or other elements of the nuclear fuel cycle in nuclear energy centers.

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[1] Submitted January 19, 1976.

The Subcommittee recognizes that the energy center idea cannot be a perfect, instant solution to all problems. While it would substantially increase the effectiveness of nuclear safeguards, the trade off could be undesirable economic effects. A reorganization and relocation of the nuclear fuel cycle industries into energy centers could lead to regionalization and loss of competition. Without that competition other ways would have to be found to keep costs and prices of these services in balance. Perhaps companies located at regional centers would have to be regulated as public utilities; or perhaps some forms of competition could be preserved among energy centers.

Conclusions

The Subcommittee concludes that:

1. Certain benefits can be reasonably expected to accrue from the establishment of Federally-owned energy centers in various electric distribution regions throughout the country.

2. This concept does not envision requiring that all energy production from nuclear energy or other sources be limited to production from such centers.

3. Energy centers would be ideal centers for development of alternative energy concepts and might prove attractive sites for the production of energy from these sources.

Recommendations

The Subcommittee recommends that serious consideration be given to legislation that would create energy centers. Careful study and examination of this concept by State and Federal governments and industry is warranted.

SEPARATE VIEWS OF SENATOR JOHN V. TUNNEY[1]

I dissent strongly from the main body of the draft subcommittee report findings and recommendations. Accordingly, I hope that you will record my opposition to printing the report as the official consensus of the Subcommittee.

I recognize that the draft is the product of extensive work and review on the part of the staff and membership of the Subcommittee. Nonetheless, I must take issue with many of its evaluations and conclusions as they relate to the feasibility and desirability of the United States' breeder reactor program. I believe that the report fails to deal adequately with many fundamental issues and questions concerning the timing, economic feasibility and safety implications of the breeder program.

My disagreements with the draft are numerous and I will not take up your time specifying each of them. However, I would like to register a strong and specific dissent to the conclusions and recommendations concerning the LMFBR program. I do not believe that the program needs to be pursued with a "new sense of urgency," nor do I foresee the need for commercialization of the LMFBR no later than the early 1990's. Neither can I accept the conclusion that "vigorous pursuit of LMFBR development at this time * * * does not represent an irreversible commitment to commercialization."

Most especially, I do not feel that ongoing review of the LMFBR program to insure that it remains in the public interest has interfered unnecessarily with the completion of the program. Moreover, to say that the Subcommittee "believes that the time has come to end the discussion over whether this Nation should have a breeder research and development program" belies the conclusion that our present efforts do not constitute irreversible commitments to commercialization. I regard the review of Federal research and development programs on a continuing basis as one of the Congress' most important Constitutional functions. To end debate on any program, but most especially on one as fraught with uncertainties as the LMFBR program, would be an abdication of that responsibility, and I regard such a course as unacceptable.

In short, I dissent from the findings, conclusions and recommendations of the draft. I would appreciate your entering that dissent on the record as appropriate, and also your entering this letter as part of the record of the Subcommittee meeting.

John V. Tunney,
U.S. Senator.

[1] As communicated in letter of December 8, 1975, from Senator Tunney to Subcommittee Chairman McCormack.

APPENDIX 1

LETTER SENT WITH QUESTIONS

The following letter, posing a series of questions relating to areas of interest to the subcommittee, was sent by Chairman Mike McCormack to the addressees listed. (The answers to this letter were included in a Jont Committee print entitled, "Issues for Consideration: Review of the National Breeder Reactor Program, August 1975.")

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., April 11, 1975.

DEAR ———: The Joint Committee has appointed an ad hoc subcommittee of its membership to review the Liquid Metal Fast Breeder Reactor Program of the Energy Research and Development Administration. I have the privilege of chairing that subcommittee.

The subcommittee plans to hold comprehensive public hearings in order to receive testimony from representatives of Federal agencies, the nuclear community and the public at large. In addition, the subcommittee plans to visit program facilities and other sites where breeder reactor development or demonstration activities are underway.

In order to develop information on principal issues for the subcommittee's consideration, I am writing at this time to request the views of those who are known to us to have participated in or shown interest in the national breeder program.

Attached is a series of questions relating to the fundamental issues of this nation's need for energy, the electrical component thereof, the alternative fuels and available resources, and the merits or demerits of a commitment to the development of a breeder reactor as a partial solution to the projected electrical energy need. These are, of course, not new questions. They have been studied in one form or another in recent years by a variety of groups, both within and outside of Government. Maximum use can be made of forecasts, earlier studies, or position papers by reference.

The subcommittee will need your comments on these issues at the earliest opportunity. In order for your response to have maximum usefulness, it should be mailed to the subcommittee by April 21, 1975. In addition, it would be helpful if you would include a summary statement of your views in your response. If convenient to do so, please provide an original and two copies of your reply.

We encourage your cooperation in this important matter.

Sincerely yours,

MIKE MCCORMACK,
Chairman, Subcommittee To Review the Liquid Metal Fast Breeder Reactor Program.

Attachment: As stated. (See p. 25.)

Addressees of April 11, 1975 LMFBR Ad Hoc Subcommittee Letter (By Category)

Governmental

Hon. William A. Anders, Chairman, Nuclear Regulatory Commission, Washington, D.C. 20555.

Dr. Philip Handler, National Academy of Sciences, 1101 Constitution Avenue NW., Washington, D.C. 20418.

Hon. Rogers C. B. Morton, Chairman, Energy Resources Council, Old Executive Office Building, Washington, D.C. 20500.

Hon. John N. Nassikas, Chairman, Federal Power Commission, 441 G Street NW., Washington, D.C. 20426.

Hon. Russell W. Peterson, Chairman, Council on Environmental Quality, Washington, D.C. 20006.

Hon. Robert C. Seamans, Jr., Administrator, Energy Research and Development Administration, Washington, D.C. 20545.

Hon. Elmer B. Staats, Comptroller General of the United States, General Accounting Office, Washington, D.C. 20548.

Hon. Russell E. Train, Administrator, U.S. Environmental Protection Agency, Washington, D.C. 20460.

Hon. Frank G. Zarb, Administrator, Federal Energy Administration, 12th & Pennsylvania Avenue NW., Washington, D.C. 20461.

LMFBR Major Program Participants

Thomas G. Ayers, Chairman, Breeder Reactor Corporation, P.O. Box 767, Chicago, Ill. 60690.

S. D. Bechtel, Jr., Chairman, Bechtel, Inc., 50 Beale Street, San Francisco, Calif. 94119.

W. B. Behnke, Assistant to the President, Commonwealth Edison Company, 72 W. Adams Street, Chicago, Ill. 60690.

G. C. Hurlbert, President, Power Systems Company, Westinghouse Electric Corporation, Westinghouse Building, Gateway Center, Pittsburgh, Pa. 15222.

Samuel Iacobellis, President, North American Rockwell, Atomics International Division, 8900 De Soto Street, Canoga Park, Calif. 91304.

Robert Laney, Deputy Director, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Ill. 60439.

Dr. Herman Postma, Director, Holifield National Laboratory, P.O. Box X, Oak Ridge, Tenn. 37830.

Dr. Robert B. Richards, General Manager, Fast Breeder Reactor Products Dept., General Electric Company, 310 De Guigne Drive, Sunnyvale, Calif. 94086.

Kenneth A. Roe, President, Burns & Roe, Inc., 700 Kinderkamack Road, Oradell, N.J. 07649.

Dr. Alexander Squire, Director, Hanford Engineering Development Laboratory, P.O. Box 1970, Richland, Wash. 99352.

Mr. Peter Van Nort, General Manager, Project Management Corp., 72 West Adams, Room 1535, Chicago, Ill. 60690.

Mr. Aubrey J. Wagner, Chairman, Tennessee Valley Authority, Knoxville, Tenn. 37902.

Public Groups

David Brower, President, Friends of the Earth, 620 C Street SE., Washington, D.C. 20003.

David Comey, Businessmen & Professional People for the Public Interest, Suite 1001, 109 N. Dearborn, Chicago, Ill. 60602.

James Cubie, Congress Watch, 133 C Street SE., Washington, D.C. 20003.

Dr. Ian Forbes, Chairman, The Energy Research Group, Lowell Technological Institute, Lowell, Mass. 01854.

Daniel Ford, Executive Director, Union of Concerned Scientists, P.O. Box 289, MIT Branch Station, Cambridge, Mass. 02139.

Dr. Albert Fritsch, Co-Director, Center for Science in the Public Interest, 1779 Church Street NW., Washington, D.C. 20036.

Elise Jerard, PH.D, Independent Phi Beta Kappa Environmental Study Group, 115 Central Park West, New York, N.Y. 10023.

John Gardner, President, Common Cause, 2030 M Street NW., Washington, D.C.

Kent Gill, President, Sierra Club, 1144 Princeton Place, Davis, Calif. 95616.

Jerry Long, Administrative Assistant, Environmental Policy Center, 324 C Street SE., Washington, D.C. 20003.

Dr. James MacKenzie, Massachusetts Audubon Society, South Great Road, Lincoln, Mass. 01773.

Laurence I. Moss, Executive Secretary, Committee on Public Engineering Policy, 2101 Constitution Avenue NW., Washington, D.C. 20418.

Glenn Paulson, Executive Director, Scientists' Institute for Public Information, 30 East 68th Street, New York, N.Y. 10021.

Arlie Schardt, Executive Director, Environmental Defense Fund, 1525 18th Street NW., Washington, D.C. 20036.

Jeremy J. Stone, Director, Federation of American Scientists, 307 Massachusetts Avenue NE., Washington, D.C. 20002.

Dr. Arthur R. Tamplin, Dr. Thomas B. Cochran, J. Gustave Speth, Esq., Natural Resources Defense Council, Inc., 917 15th Street NW., Washington, D.C. 20005.

Other Industrial Organizations

Dr. Marion Clawson, Acting President, Resources for the Future, 1755 Massachusetts Avenue NW., Washington, D.C. 20036.

W. Donham Crawford, President, Edison Electric Institute, 90 Park Avenue, New York, N.Y. 10016.

J. H. MacMillan, General Manager, Babcock & Wilcox, P.O. Box 1260, Lynchburg, Va. 24505.

Carl E. Bagge, President, National Coal Association, 1130 17th Street NW., Washington, D.C. 20036.

Dr. William O. Baker, President, Bell Laboratory, Murray Hill, N.J. 07974.

Dr. Cyril Comar, Chairman, Department of Physical Biology, Cornell University, Ithaca, N.Y.

Herman Dieckamp, President, General Public Utility Service Corporation, Parsippany, N.J. 07054.

W. W. Finley, Jr., President, General Atomic Company, P.O. Box 81608, San Diego, Calif. 92138.
William R. Gould, Executive Vice President, Southern California Edison, 2244 Walnut Grove Avenue, Rosemead, Calif. 91770.
Donald F. Hart, President, American Gas Association, 1515 Wilson Boulevard, Arlington, Va. 22209.
Frank N. Ikard, President, American Petroleum Institute, 1801 K Street NW., Washington, D.C. 20006.
Milton Klein, Special Assistant for Energy Plans, Mitre Corporation, West Gate Research Park, McLean, Va. 22101.
Guy Nichols, Chairman, National Association of Electric Companies, 1140 Connecticut Avenue NW., Suite 1010, Washington, D.C. 20036.
Robert Partridge, Executive Vice President and General Manager, National Rural Electric Cooperative Association, 2000 Florida Avenue NW., Washington, D.C. 20009.
Alex Radin, General Manager, American Public Power Association, 2600 Virginia Avenue NW., Washington, D.C. 20037.
Arthur Santry, President, Combustion Engineering, Inc., 1000 Prospect Hill Road, Windsor, Conn. 06095.
John Simpson, Chairman, Atomic Industrial Forum, 475 Park Avenue South, New York, N.Y. 10016.
Dr. Chauncey Starr, President, Electric Power Research Institute, 2412 Hillview Avenue, P.O. Box 10412, Palo Alto, Calif. 94304.
Arthur M. Wood, Chairman of the Board, Sears, Roebuck & Co., Sears Tower, Chicago, Ill. 60684.
Dr. Ronald Doctor, The RAND Corporation, 1700 Main Street, Santa Monica, Calif. 90406.

Others

Dr. Maurice A. Adelman, Department of Economics, Massachusetts Institute of Technology, Cambridge, Mass. 02139.
Dr. Hannes Alfvén, Physics Department, University of California, San Diego, Calif. 92037.
Dr. Manson Benedict, 25 Byron Road, Weston, Mass.
Dr. Hans Bethe, Cornell University, Ithaca, N.Y.
Dr. Irvin C. Bupp, Harvard Business School, Harvard University, Cambridge, Mass. 02138.
Dr. Duane Chapman, 304 Warren Hall, Cornell University, Ithaca, N.Y. 14853.
Dr. Bernie Cohen, Department of Physics, University of Pittsburgh, Pittsburgh, Pa. 15213.
Dr. Barry Commoner, Director, Center for the Biology of Natural Systems, Washington University, Box 1126, St. Louis, Mo. 63130.
Robert Georgine, President, Building Trades Council, 815 16th Street NW., Washington, D.C. 20006.
Dr. Lawrence Hafsted, Kent Island, Chester, Md. 21619.
Dr. Alan Hammond, *Science*, American Association for the Advancement of Science, 1515 Massachusetts Avenue NW., Washington, D.C. 20036.
Dr. John Holdren, Assistant Professor, University of California, Berkeley, Calif.
Hon. Chet Holifield, 2001 Lincoln Avenue, Montebello, Calif. 90640.

Dr. David R. Inglis, Professor of Physics, University of Massachusetts, Department of Physics and Astronomy, Amherst, Mass. 01002.
Dr. Allen Kneese, Department of Economics, University of New Mexico, Albuquerque, N. Mex. 87131.
Dr. Ralph E. Lapp, 7215 Park Terrace Drive, Alexandria, Va. 22307.
Dr. Paul MacAvoy, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, 50 Memorial Drive, Cambridge, Mass. 02139.
Dr. Margaret Mead, American Museum of Natural History, 77th Street & Central Park West, New York, N.Y. 10024.
Ralph Nader, Center for the Study of Responsive Law, 1156 19th Street NW., Washington, D.C. 20008.
Dr. David J. Rose, Nuclear Engineering Department, Massachusetts Institute of Technology, Cambridge, Mass. 02139.
Dr. Glenn T. Seaborg, University Professor of Chemistry, Lawrence Radiation Laboratory, University of California, Berkeley, Calif. 94720.
Dr. Frederick Seitz, President, Rockefeller University, New York, N.Y. 10021.
Milton Shaw, Energy Consultant, 1156 15th Street NW., Suite 302, Washington, D.C. 20005.
Dr. Jules Stratton, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. Harold C. Urey, Department of Chemistry, University of California, San Diego, Calif. 92037.
Dr. James D. Watson, Dr. John T. Edsall, Dr. George Wald, Biological Laboratories, Harvard University, 16 Divinity Avenue, Cambridge, Mass. 02138.
Dr. Alvin Weinberg, 111 Moylan Lane, Oak Ridge, Tenn.
Dr. Robert Williams, Institute for Public Policy Alternatives, 99 Washington Street, Albany, N.Y. 12201.
Dr. Richard Wilson, Professor of Physics, Harvard University, Cyclotron Laboratory, Cambridge, Mass. 02138.
Dr. Walter H. Zinn, 1155 Ford Lane, Dunedin, Fla. 33528.

APPENDIX 2

SUMMARY OF HEARINGS AND OTHER ACTIVITIES OF THE JOINT COMMITTEE ON ATOMIC ENERGY'S SUBCOMMITTEE TO REVIEW THE NATIONAL BREEDER REACTOR PROGRAM

EXCERPTS FROM THE CONGRESSIONAL RECORD

April–July, 1975

[From the Congressional Record, Apr. 28, 1975]

AD HOC SUBCOMMITTEE TO REVIEW LIQUID METAL FAST BREEDER REACTOR PROJECT

(Mr. McCORMACK asked and was given permission to address the House for 1 minute to revise and extend his remarks and include extraneous matter.)

Mr. McCORMACK. Mr. Speaker, as most of the Members are probably aware, the Joint Committee on Atomic Energy has created a new special ad hoc committee to review this Nation's liquid metal fast breeder reactor project.

Tomorrow, at 2 p.m., the subcommittee will hold its first briefing. Dr. Gerald F. Tape, U.S. Ambassador to the International Atomic Energy Commission and president of Associated Universities Inc., will relate the historical developments of this Nation's civilian nuclear power program, starting with the early days of the Manhattan Project and progressing through the decision that made the liquid metal fast breeder reactor, as the President designated it, "this Nation's No. 1 energy project."

In addition, Mr. Ed Johnson, head of E. R. Johnson and Associates, will describe the uranium fuel cycle, describing for the Members the entire process, starting with the mining of uranium, and following it through milling and purification, the fabrication of fuel elements, what happens in a nuclear reactor, how uranium is recycled, and the plutonium recycle concept.

This briefing will be extremely valuable for any Member who wishes to update himself on this subject. It will be held in the Joint Committee public hearings room in room S-407. All Members are urged to attend. The meeting is open to the public.

FIRST COMMITTEE REVIEW OF THE LIQUID METAL FAST BREEDER REACTOR PROGRAM

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Wednesday, April 30, 1975

Mr. McCORMACK. Mr. Speaker, the Joint Committee's Subcommittee on Review of the National Breeder Reactor Program began a series of briefings on Tuesday of this week and heard from Dr. Gerry Tape on the historical background of the civilian nuclear power program and from Mr. E. R. Johnson on the characteristics of the uranium fuel cycle. I ask to be included in the RECORD at the conclusion of my remarks a summary of the presentations which were heard from these speakers.

Tomorrow, May 1, the subcommittee will convene at 2 p.m. for a second briefing session during which we will hear a description of the basic nuclear reactor types by Dr. E. Linn Draper and a description of the enriching process and plutonium recycle by Mr. George Quinn.

I would like to publicly acknowledge the fine presentations given by Dr. Tape and Mr. Johnson. The material was excellent and subcommittee members in attendance had the opportunity to question the speakers on matters of special interest to them. I was particularly pleased that the following members of the ad hoc subcommittee participated in yesterday's briefing session: Senator Howard Baker, Senator Clifford Case, Congressman Reno Roncalio, Congressman Frank Horton, and Congressman Andrew Hinshaw.

Summary of Tuesday, April 29, 2 p.m. briefing session follows:

Dr. Gerald F. Tape, presently serving as U.S. Ambassador to the International Atomic Energy Agency—IAEA—briefed the Ad Hoc Subcommittee on the Breeder Reactor Program on the subject of the historical development of the U.S. civilian nuclear power program. The briefing summarized activities of the Manhattan project period, which included the first successful sustained nuclear chain reaction in December of 1942 and the construction of a variety of research and plutonium production reactors. The establishment of the Atomic Energy Commission in 1946 led in the late forties and early fifties to an expansion of uranium ore procurement and enrichment activities, and to reactor development activities especially for production and military applications. This period included the first experimental breeder reactor—EBR–I, pressurized water reactors for submarine propulsion and materials testing reactors.

The Atomic Energy Act of 1954 included specific provisions for the purpose of enhancing industrial participation by permitting access to technical data and private ownership of nuclear reactors, and by establishing a framework for licensing and regulatory activities. It also made possible programs for international cooperation. In 1955, a power reactor demonstration program was begun to strengthen utility and equipment manufacturers' involvement in developing a broad spectrum of plant types and sizes. Several methods of Government assistance were provided to enhance commercial participation. These activities led in the late fifties to defining economic targets and to the establishment of longer range goals in economics and resource conservation.

In 1962, a report to the President on civilian nuclear power was prepared by the Atomic Energy Commission. It was concluded that the nuclear power program should continue on an expeditious basis. Commission support was to be continued with added emphasis on stimulating industrial participation, including: First, early construction of plants utilizing competitive nuclear reactor types; second, development, construction and demonstration of advanced converter reactors to improve the economics and the use of nuclear fuels; and third, intensive development and, later, demonstration of breeder reactors to fill the long-range needs of utilizing fertile as well as fissile fuels.

Further objectives for the future nuclear power program were established to foster and support the growing use of nuclear energy and, importantly, to guide the program in such directions as to make possible the exploitation of the vast energy resources latent in the fertile materials, uranium-238 and thorium. Specifically, these included the further construction of demonstration reactors, the early establishment of a self-sufficient nuclear power industry, and the development of improved converter and, later, breeder reactors.

Continued development of the nuclear power industry in the mid-sixties to early seventies saw a major role taken by private industry, Government research and development emphasis on safety, Government regulatory emphasis on engineered safeguards and quality assurance, and the emergence of several issues such as operational reliability, et cetera. In addition, further emphasis was directed toward breeder reactors, with an AEC commitment in 1968 to a strong research and development program, and with a Presidential energy message in 1971 establishing the operation of a demonstration liquid metal fast breeder reactor as a national goal by 1980. A cooperative demonstration program for the construction of an LMFBR on a utility grid was established in 1972, and work on that project—Clinch River Breeder Reactor—continues today.

Contributions to LMFBR technology have been made by a number of experimental plants operated in the United States as well as others in foreign nations. In particular it was noted that the United Kingdom, France, and the U.S.S.R. are currently operating liquid metal breeder reactor demonstration powerplants considerably ahead of the U.S. schedule for its first demonstration plant. It was noted at this juncture that the ad hoc subcommittee was developing plans for visits to these facilities.

BRIEFING ON THE URANIUM FUEL CYCLE—PRESENTED BY E. R. JOHNSON

Mr. E. R. Johnson, president of E. R. Johnson Associates, presented a thorough and informative review of the processing steps of the nuclear fuel cycle. The review covered a description of the cycle from the initial mining process through plans for disposition of wastes. Key points noted as listed below.

From the initial ore that is mined, U_2O_8, or yellow cake, is produced which contains both U–238 and a small fraction of U–235, the fissionable isotope. The yellow cake in turn is converted into a gaseous form which is the form needed in order to increase the fraction of U–235 in the uranium at the gaseous diffusion plants. The enriched uranium is then converted to an oxide powder which

is used to make reactor fuel elements. The initial oxide powder is approximately 60 percent dense; through a sintering process the oxide is brought close to 100 percent of theoretical density. The pellets are then stacked into zirconium tubes and sealed. These tubes or fuel pins become the basic fuel for the reactor. Approximately 45,000 fuel pins are needed to fuel a large sized reactor.

After a reactor has operated for a specified period of time products from the fission process have increased to the point where it becomes necessary to refuel the reactor, or typical plants, this occurs approximately once a year. After fuel is removed from the reactor, reprocessing of the fuel is necessary such that the uranium that has not been used up can be returned to the fuel cycle for making new fuel while the radioactive waste products can be prepared for storage.

Mr. Johnson described the extensive care taken in transporting the nuclear materials at each step of the process. The gaseous form of the uranium is shipped in specially designed casks similar to chlorine shipping containers. After fuel has been irradiated in the reactor, the fuel shipping casks require massive shielded containers—typically lead or depleted uranium. These containers are designed to very strict standards. The cask must not leak radioactive material even after the following tests:

First, a 30-foot drop onto an unyielding surface;

Second, a puncture test which is a drop of the cask from four feet onto a spike;

Third, survival in a fire of greater than 1,400° F. for 30 minutes; and

Fourth, submersion in water for 8 hours.

Potential methods of waste disposal were discussed. Presently, high level radioactive wastes are being held in specially designed tanks. It was observed that while there have been leaks of radioactive material from the tanks used to store wastes generated in the military program, there have been no leaks from the tanks used to store wastes generated by commercial power reactors.

Mr. Johnson explained how special storage cylinders are to be used to store wastes in retrievable surface storage until a method of permanent disposal is decided upon.

It was necessary to adjourn before Mr. Johnson finished his presentation. He will present the remainder of his material at a later date.

April 30, 1975

Nuclear Power Program Briefings

(Mr. McCormack asked and was given permission to address the House for 1 minute and to revise and extend his remarks.)

Mr. McCormack. Mr. Speaker, the Joint Committee's Subcommittee on Review of the National Breeder Reactor Program began a series of briefings on Tuesday of this week and heard from Dr. Gerry Tape on the historical background of the civilian nuclear power program and from Mr. E. R. Johnson on the characteristics of the uranium fuel cycle. I will include a summary of the presentations which were heard from those speakers in the Extensions of Remarks in today's Record.

Tomorrow, May 1, the subcommittee will convene at 2 p.m. for a second briefing session during which we will hear a description of the baisc nuclear reactor types by Dr. E. Linn Draper and a description of the uranium enriching process and plutonium recycle by Mr. George Quinn.

I would like to publicly acknowledge the fine presentations given by Dr. Tape and Mr. Johnson. The material was excellent and subcommittee members in attendance had the opportunity to question the speakers on matters of special interest to them. I was particularly pleased that the following members of the subcommittee participated in yesterday's briefing session: Congressman Teno Roncalio, Congressman Frank Horton, Congressman Andrew Hinshaw, Senator Howard Baker, and Senator Clifford Case.

May 5, 1975

Joint Committee Review of the Liquid Metal Fast Breeder Reactor Program

(Mr. McCormack asked and was given permission to address the House for 1 minute and to revise and extend his remarks.)

Mr. McCormack. Mr. Speaker, in continuance of my practice of keeping this body informed of the activities of the Joint Committee's Subcommittee on

Review of the national breeder reactor program, I have the following report. On Thursday of last week, the subcommittee held its second in a series of briefings and heard Dr. E. Linn Draper on nuclear reactor types and Mr. George Quinn on the uranium enriching process. I was pleased that Senator CLIFFORD CASE, a member of the ad hoc subcommittee, was able to participate in this briefing.

I include in the Extensions of Remarks a summary of the presentations which were heard from our two speakers.

On Tuesday, May 6, the subcommittee will convene at 2 p.m. for a third briefing session during which we will hear a presentation on the present status of civilian nuclear powerplants, including performance and reliability, by Mr. Willian S. Lee and another on the Clinch River breeder demonstration project by Mr. Wallace Behnke.

As a further step in its review of the breeder program, the subcommittee will hold a public hearing at 2 p.m. on Wednesday, May 7, 1975, at which time the Honorable Russell E. Train and the Honorable Frank G. Zarb will appear as witnesses.

Mr. Train, Administrator of the Environmental Protection Agency will present his Agency's recently released views on the proposed final environmental impact statement on the liquid metal fast breeder reactor program, Mr. Zarb, Administrator of the Federal Energy Administration, is scheduled to present the administration's views on projections of electrical load growth, the prospective role on the liquid metal fast breeder reactor, and related matters.

MAY 1 BRIEFING ON THE LIQUID METAL FAST BREEDER REACTOR PROGRAM

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Monday, May 5, 1975

Mr. McCORMACK. Mr. Speaker, Dr. E. Linn Draper, professor, the University of Texas, briefed the Joint Committee's Ad Hoc Subcommittee on the breeder reactor program on the subject of the various types of reactors presently in use or under development. He presented an excellent overview of nuclear reactor design including operating principles and safety features. Key aspects are summarized below.

The production of electricity is basically through the heating of water to produce steam which in turn drives a turbine-generator which produces electricity. The principal difference between a conventional or fossil fueled plant and a nuclear plant is in the heat source to produce the steam. Heat in the nuclear reactor results from splitting U-235 atoms. The rate at which heat is produced is determined by the number of atoms being split—or undergoing the fissioning process. The rate of fissioning in the reactor is governed by control rods. Should one wish to essentially stop the fissioning process, the control rods are simply inserted into the reactor core.

Dr. Draper presented pictures and explained the different types of nuclear reactor. The boiling water reactor, or BWR, operates at approximately 1,000 pounds pressure at approximately 550° F. The steam produced in the reactor directly drives the turbine which turns the generator. The reactor vessel for the BWR is 80 feet high, 40 feet in diameter, and approximately 5 inches thick. This reactor type is manufactured by the General Electric Co.

The pressurized water reactor operates at 2,000 pounds and between 500–600° F. Since water under these conditions does not boil, the heated water is passed through a heat exchanger which transfers the heat to water in a second loop. This loop operates at lower pressure and, therefore, boiling of water does occur. The steam produced drives the turbine. The PWR vessel is 40 feet high, 20 feet in diameter, and approximately 9 inches thick. This concept is marketed by Westinghouse Electric Corp.; Combustion Engineering, Inc.; and the Babcock and Wilcox Co.

The high temperature gas reactor, developed by General Atomic Co., uses helium as the primary coolant and operates at 1,400° F. This higher temperature allows a higher thermal efficiency for the HTGR of about 40 percent compared to 32 percent for water reactors.

The characteristics of the breeder reactor were described. One basic aspect of the breeder reactor, which would be cooled by liquid sodium, is that it would allow a factor of 60 increase in the use of uranium over that of the present water reactors.

Dr. Draper presented the safety considerations that are involved in reactor design. The "defense-in-depth" approach covers:

First, detailed engineering design to assure reactors are operated safely under normal conditions and for anticipated operational malfunctions. A stringent quality assurance program is undertaken at all phases of design and construction.

Second, engineered safety features are included in the design of a reactor to assure control of the fission process and adequate heat removal under postulated off-normal conditions. It was pointed out that this was the normal approach that any kind of plant in any industry would take during design, construction, and operation. For the reactor industry, however, a third step is taken, namely the use of a design basis accident—DBA. A low probability severe event is postulated as the DBA; the reactor is required to be designed to withstand such an accident in a safe manner. To assure this defense-in-depth is carried out fully, each reactor must go through a rigorous licensing review process. This process includes a positive finding to be made by the Nuclear Regulatory Commission prior to plant construction and prior to plant operation. Public hearings are required in the construction permit review and are offered and may be held at the operating license stage.

Dr. Draper also provided perspective as to the potential risk to the public as a consequence of the operation of nuclear reactors. Included in this discussion, reference was made to the AEC safety study made by Dr. Norman Rasmussen of MIT. Dr. Draper noted the extremely low risk posed by reactor operations especially when compared to risks that society commonly accepts.

Mr. George F. Quinn, an expert in the area of uranium enrichment, presented an excellent review of the uranium enrichment process. It was shown that only 0.7 percent of natural uranium is present in the form of the fissionable isotope U–235, and that most types of nuclear power reactors require fuel with a higher percentage of this material. For example, light water reactors—the prevalent type in the United States—require fuels of 2 to 4 percent enrichment in U–235, and high temperature gas-cooled reactors, which are coming into commercial usage, require fully enriched—93 percent—uranium. Therefore, an enrichment process is required to support the nuclear industry.

It was shown that in a typical enrichment arrangement the feed material—0.7 percent U–235—is transformed into a product containing 4 percent U–235, leaving a "tails" material assaying 0.2 percent U–235. In this process, approximately 70 percent of the U–235 in the feed stream is recovered as product. A higher percentage could be recovered, but the process would then become more costly. On the other hand, one could operate an enrichment process yielding a higher tails assay and, therefore, requiring less "separative work" and lower cost. However, in this case a greater amount of uranium feed would be needed to produce the same amount of useful product, and one must, therefore, balance economics versus resource availability and enrichment plant capabilities in deciding which enrichment approach to employ. It was noted that in either case, the stockpiled tails—whether 0.2 or 0.3 percent in U–235 assay—could eventually be used as fuel in breeder reactors.

The gaseous diffusion process was identified as the most economic process employed on a production scale to date. A description of this process was presented, and its operating principles described. The need for multiple enrichment stages to reach a desired enrichment level was pointed out. Finally, the locations of the three existing gaseous diffusion plants in the United States—Oak Ridge, Tenn.; Portsmouth, Ohio; and Paducah, Ky.—were noted, and a brief discussion provided of the cascade improvement program and the cascade uprating program, which would lead to a 60-percent increase in separative work capacity. These improvements require substantial capital funds but only a moderate increase in electricity consumption.

Alternative enrichment process such as gas centrifuge and laser isotope separation, and the subject of plutonium recycle were not discussed for reasons of available time, but additional information on these matters has been made available to the subcommittee.

Report of Subcommittee To Review the Liquid Metal Fast Breeder Reactor

hon. mike m'cormack of washington in the house of representatives

Wednesday, May 7, 1975

status of nuclear power

Mr. McCormack. Mr. Speaker, on May 6, 1975, Mr. William Lee, senior vice president of Duke Power Co., presented an excellent briefing to the ad hoc subcommittee of the Joint Committee on Atomic Energy on the present status of

civilian nuclear power. It was shown that today's nuclear power plants were built because they represented the best energy supply alternative, particularly in that they provided the lowest cost energy to consumers, no penalty to shareholders' earnings, reliability comparable to fossil-fueled plants of the same size and vintage, and safe and environmentally acceptable operation. Now that these plants are providing up to 9 percent of U.S. electrical generating capacity they have essentially met these promises with the exception of shareholders' earnings, in that the high capital costs of nuclear plants and delays by regulatory bodies in reflecting these costs in utilities rate bases have resulted in lower earnings. On the other hand, very substantial savings to consumers have been achieved on the order of $750 million in 1974, due primarily to the lower operating and fuel costs of nuclear power plants.

Mr. Lee also presented a comparison of the operating availability and capacity factors of nuclear- and fossil-fueled plants over the 10-year period 1964–73. It was shown that nuclear plant availability was 78.8 percent as opposed to 72.9 percent for fossil-fueled plants. Similarly, the average nuclear capacity factor over this period was 64.2 percent, as compared to 59.5 percent for fossil plants. More currently, in the last half of 1974, fossil plant availability exceeded that of nuclear plants, 76.1 percent to 71.5 percent. The turnaround was due to the large number of nuclear plants coming online in 1974, and the maturing of fossil plants. However, nuclear plant capacity factors still exceeded those of fossil plants in this period, 61.8 percent to 57.3 percent.

Looking to the future, it was shown that by 1980 100 nuclear powerplants are expected to be online representing a nuclear capacity 135 percent greater than that available today. The flow-through savings to consumers are expected to reach $3.5 billion, or $7 per capita. A substantial savings in oil consumption will also result, on the order of 750,000 barrels per day. An even more substantial increase in the use of coal will also be achieved.

Mr. Lee reported that the most significant near-term problems which might affect the achievement of these goals are financing, licensing difficulties, and delays from intervention. Other problems, considered solvable by the utility industry, are availability of manpower, shop capacity and materials, quality assurance, and availability for the long term. The areas of enrichment, reprocessing, waste disposal, safeguards, Price-Anderson, and public acceptance all require continued attention.

In summary, it was reported that the use of nuclear power has resulted in very substantial savings to consumers, and that nuclear plant reliability experience has been more than satisfactory in comparison to fossil-fueled plants. Further, the future of nuclear power, while faced with some problems, is bright and of substantial benefit to the Nation. In this respect, Mr. Lee reported the breeder is needed and must be the next step in national energy production, so as to achieve maximum ultilization of our limited uranium resources.

CLINCH RIVER BREEDER DEMONSTRATION PROJECT

Mr. Wallace B. Behnke, executive vice president of Commonwealth Edison Co. gave the ad hoc subcommittee an excellent briefing on the Clinch River breeder reactor, a demonstration project in the LMFBR program. In his briefing, Mr. Behnke discussed the following topics:

Why utilities are interested in the LMFBR.
Chronology of utility involvement leading to the Clinch River project.
Description of the Clinch River project.
Status of the Clinch River project.
Near-term milestones of the Clinch River project.

Mr. Behnke said the utilities favor the LMFBR because they project that it will provide power at a lower cost, provide electricity with less environmental impact in such areas as land use for fuel mining, and preserve the nuclear option over the long term. Preserving the nuclear option is important because in Mr. Behnke's mind there is no question that the country must turn to nuclear power and coal to meet its long-term, electric power generation needs.

Mr. Behnke presented the following chronology of utility involvement in the Clinch River project:

CHRONOLOGY OF UTILITY PARTICIPATION

1965–1970: The Edison Electric Institute conducted studies on the feasibility of the breeder concept. These studies and studies done in other countries concluded that a large scale demonstration of the LMFBR was needed.

1967: Electric utility industry conducted studies of conceptual designs for LMFBRs.

1969: Congress authorized AEC to embark on a two-phase approach for the LMFBR Demonstration Plant. The first phase, the Project Definition Phase, permitted all participants to better understand and define the technical and economic characteristics of the demonstration plant. The second phase, the Definitive Cooperative Arrangement Phase, involves the design, construction and operation of the demonstration plant.

1971: AEC established the Senior Utility Steering Committee and the Senior Utility Technical Advisory Panel to seek advice and assistance in obtaining support from the electric utility industry. Over 700 utilities pledged $257 million in 10 equal annual installments.

1971: AEC requested proposals from utility groups to own the demonstration plant.

1971: President issued energy message calling for LMFBR demonstration by 1980.

1972: In January, the AEC accepted the joint proposal of Commonwealth Edison and the Tennessee Valley Authority as the basis for negotiation on a Government utility arrangement. In March, Project Management Corporation and Breeder Reactor Corporation were formed to represent the utility organizations. Also in March, proposals were solicited from the reactor manufacturer participants in the Project Definition Phase and qualified architect engineer firms.

In November, Westinghouse was selected to be lead reactor manufacturer with Atomics International and General Electric as supporting reactor manufacturers.

In December, Burns and Roe was selected as the architect engineer.

1973: Principal Project Agreements between participants were signed.

Mr. Behnke described the Clinch River project in terms of its objectives, urgency, and plant description. He said the project's objectives were to:

(1) provide needed experience in the areas of engineering, construction and operation; (2) confirm assumptions on the environmental, reliability, maintenance and safety aspects; (3) confirm projections that the breeder will be an economic producer of electricity; and (4) build an integrated LMFBR supply industry.

Mr. Behnke feels it is urgently necessary to proceed with the Clinch River project and the breeder program for the following reasons:

To maximize savings to the consumers which he estimates as $76 billion if the breeder is commercially available by 1989. He projected that the savings would be reduced to $43 billion if commercial introduction is delayed until 1999.

To reduce the environmental impact of electrical production resulting from factors such as fuel mining.

To keep the breeder on the critical path to development in case of schedule slippages.

To minimize the impact of inflation on cost.

The Clinch River project will be a 380-megawatt electric plant. The site is presently undeveloped. Work cannot begin on the site until authorization is received from the Nuclear Regulatory Commission.

In his comments on the present status of the Clinch River project, Mr. Behnke said a construction permit and a limited work authorization from NRC have been applied for and the preliminary safety analysis report has been sent to NRC.

Mr. Behnke enumerated the following near term milestones for the Clinch River project:

June 1975: Sign revised project agreements.

July 1975: Award construction contract.

September 1975: Relocate staff to Oak Ridge.

November 1975: Receive limited work authorization and start site work.

January 1977: Start construction work.

1982: Put plant on line.

May 12, 1975

Breeder Reactor Program Hearing

(Mr. McCormack asked and was given permission to address the House for 1 minute and to revise and extend his remarks.)

Mr. McCormack. Mr. Speaker, on last Wednesday, May 7, the Joint Committee on Atomic Energy's Subcommittee on Review of the National Breeder Reactor Program held a public hearing to explore and clarify the position of the Environmental Protection Agency regarding the Energy Research and Development Administration proposed final environmental statement on the liquid metal fast breeder reactor program.

The subcommittee had the benefit of testimony by the Honorable Russell E. Train, Administrator of the Environmental Protection Agency, and the views of the Honorable Frank G. Zarb, Administrator of the Federal Energy Administration, presented by Mr. John Hill, FEA Deputy Administrator.

EPA Administrator Russell Train corrected misleading stories which appeared in the press several days before which implied that EPA was recommending a delay in the nuclear breeder program. Mr. Train reaffirmed his support and the support of EPA of the Clinch River Liquid Metal Fast Breeder Reactor and emphasized that EPA has made no recommendation for any delay in commercialization of the breeder program. Mr. Train did review the EPA comments on the breeder program pointing out that using low energy demand projections, a delay in the program "might be accommodated." A more detailed report of this hearing is included in my Extension of Remarks in today's Record.

Mr. Hill reviewed the energy demand projections of the FEA and stated the administration's view that the breeder is needed to preclude a possible uranium shortage within a few decades and in order that the public will fully benefit from additional low cost and environmentally clean nuclear generated electricity. Mr. Hill further stated that it was Mr. Zarb's view that the breeder demonstration program should not be delayed.

I was pleased that the following subcommittee members were able to participate in the hearing: Senators Pastore and Case, Congressmen Price, Young, and Horton.

Review of the Nuclear Breeder Program—Hearing of May 7

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Monday, May 12, 1975

Mr. McCormack. Mr. Speaker, on May 7, the Honorable Russell E. Train, Administrator of the Environmental Protection Agency, appeared before the breeder review committee and discussed the Agency's recently completed review of the Energy Research and Development Administration's proposed final environmental impact statement on the breeder reactor program. In the view of the subcommittee, there were a number of comments made in the press and in the April 23, 1975, letter from EPA to ERDA concerning the impact statement which needed clarification.

Mr. Train pointed out that, contrary to implications in a recent story in the New York Times, the EPA had not suggested any delay in the nuclear breeder program, nor in the Clinch River liquid metal breeder nuclear construction project. Mr. Train stated that using revised low energy demand projections from the Federal Energy Administration, the EPA had concluded that—

A delay of four to twelve years might be accommodated without significantly reducing the uranium conservation value of the breeder.

However, he emphasized that EPA did not recommend any such delay, and observed that projected delays assumed by the Energy Research and Development Administration and the joint committee overlapped with his assumptions for what delays might be accommodated without harm in the breeder program.

Committee members brought out the point that there were a number of comments made in the EPA letter which would be used by some to suggest that there was disagreement within the executive branch concerning the need for and the priority associated with the development and ultimate commercialization of the liquid metal fast breeder reactor.

Mr. Train agreed to furnish a letter to the joint committee which would clarify a number of issues discussed at yesterday's hearing and indicate his strong support for proceeding with the Clinch River breeder demonstration project.

Mr. John Hill, Deputy Administrator of the Federal Energy Administration, presented the prepared testimony submitted by the Honorable Frank G. Zarb, Administrator, since Mr. Zarb was not able to appear before the subcommittee due to a conflict in his schedule. It was pointed out that in view of the dwindling supplies of domestic oil and natural gas, that greater use of coal and nuclear energy to produce electricity should be expected. An electrical demand growth rate of about 6 percent per year—a rate much higher than that expected for total energy demand—should be expected. There was recognition that if conservation measures are adopted and effectively implemented, the electrical demand growth rate might be as low as 5 percent per year. FEA believes that it would be prudent to plan and provide electrical generating capability at a somewhat higher rate than would be anticipated. Mr. Hill went on to say that any projections 25

to 45 years into the future must be considered to be highly speculative. He stated that this country should not base an important energy decision on the breeder reactor on such projections for the following reasons:

First, the current picture of domestic resources already points in the direction of greater dependence on uranium and coal, and the long-term use of uranium depends inevitably on the breeder;

Second, the longer we wait to demonstrate the breeder the more it will cost;

Third, in the final analysis, the pace of industrial introduction of the breeder will be determined in the marketplace. But this will only occur if the breeder has been demonstrated; and

Fourth, there is an urgent need to proceed now with the LMFBR demonstration plant in order to determine at the earliest possible date whether this particular breeder approach will prove dependable on a commercial scale.

With respect to consideration of our total energy picture, FEA believes there is little question that we will have an increase in dependence on nuclear power and a need for development of a breeder reactor. The following information on this point was submitted:

Nuclear power now provides 8% of our electrical needs and is projected to provide about 30% by 1985 based on the 200 plants now operating or on order. Such a major element of the Nation's generating capacity *must* have an assured source of fuel.

There are at present about 700,000 tons of uranium in proven reserves. An additional 2,500,000 tons of uranium resources are projected to be available, but are not proven.

The 200 reactors already in operation, or on order, will use over their lifetime at least 1,300,000 tons of uranium, almost twice the amount of *proven* reserves.

While it is hoped that new uranium discoveries will be made to increase the base of proven reserves, the above facts clearly indicate that we need the breeder to preclude a uranium shortage.

Without the breeder, electric utilities will not be able to assure themselves a source of fuel supply as a prerequisite to ordering new plants, and we could thus be faced with a rapid decline of the nuclear industry. The public will be denied the benefits of additional low cost and environmentally clean, nuclear generated electricity. Even with our most optimistic assumptions regarding both conservation and the increasing utilization of coal for electrical generation, we will not be able to meet the projected demand for electricity without nuclear power. The consequences of inadequate electric power could be grave indeed for our economy.

Meetings of Nuclear Breeder Review Committee

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Monday, June 9, 1975

Mr. McCormack. Mr. Speaker, to continue my practice of keeping Members of the House advised of the proceedings of the Joint Committee on Atomic Energy's Subcommittee To Study the Nuclear Breeder Reactor Program, I would like to announce that the subcommittee will hold hearings tomorrow, Tuesday, June 10, and Wednesday, June 11. Both meetings will start at 2 p.m. in the public hearing room of the Joint Committee on Atomic Energy.

At tomorrow's hearing the subcommittee will receive testimony on energy growth trends for this country for the balance of this century. Witnesses with a variety of perspectives on this subject will testify. These include Mr. Alan McGowan of the Scientists' Institute for Public Information, Dr. John Holdren of the University of California at Berkeley, Dr. Bruce Netschert of the National Economics Research Institute, and Mr. Roger LeGassie of the Energy Research and Development Administration.

On Wednesday the subcommittee will receive testimony concerning alternate energy sources, their potential, and dates of availability. We will receive testimony from Dr. Allen Hammond of the American Association for the Advancement of Science, Mr. Mark Messing, of the Environmental Policy Center, Dr. John Teem, Assistant Administrator for Advanced Energy Systems of the Energy Research and Development Administration, and Dr. Joseph Oxley, of Battelle Memorial Institute.

I want to reemphasize that Members of the Congress and their staffs are invited to attend these hearings, as is the general public. I also want to remind the Members that if they have questions concerning nuclear energy, the nuclear breeder

program, or the Clinch River liquid metal breeder reactor project, they should contact members of the Joint Committee on Atomic Energy. We will be happy to provide responsible answers and information.

Report of Subcommittee To Review Liquid Metal Fast Breeder Reactor

hon. mike m'cormack of washington in the house of representatives

Wednesday, June 11, 1975

Mr. McCormack. Mr. Speaker, in continuance of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Subcommittee To Review the National Breeder Reactor Program, I have the following report:

Yesterday, the subcommittee in open session received testimony from invited witnesses on the subject of energy trends. This session included coverage of projected total energy demand and projected electrical energy demand in the United States throughout the remainder of this century, the effect of energy conservation and its limitations, the growth rate of electrical energy, and the significance of recent reductions in electrical energy growth rates.

Testimony was presented by Mr. Alan McGowan, president, Scientists' Institute for Public Information; Dr. John Holdren, University of California, Berkeley; Dr. Bruce Netschert, vice president, National Economics Research Associates, Inc.; and Mr. Roger LeGassie, Assistant Administrator for Planning and Analysis, Energy Research and Development Administration.

I was pleased that Senator Clifford Case, Congressmen John Young, John B. Anderson, Frank Horton, and Andrew J. Hinshaw were able to attend and participate in the questions of the witnesses.

My opening remarks and a summary of the material presented and the ensuing discussion follow:

opening remarks by chairman m'cormack, june 10, 1975

Ladies and gentlemen, I am pleased to welcome you to the first in this series of Joint Committee hearings on the National Breeder Reactor Program. This Subcommittee, appointed to review the breeder program, was established on March 19, 1975, and all members of the Joint Committee on Atomic Energy are members of the Subcommittee.

The mission of this special Subcommittee is to examine the entire breeder reactor program as well as the Clinch River Breeder Demonstration Reactor, which has been authorized and partially funded. This examination includes evaluation of the various concerns that have been expressed and questions that have been raised within the Congress and outside by members of the public with respect to several fundamental issues such as the need for Program, the potential benefits to be realized from it, and the attendant risks associated with ultimate widespread commercial use of this type of electrical generating station.

As a first step toward obtaining information and views on these matters from all sectors, the Subcommittee dispatched letters on April 11, 1975, seeking comments on the principal issues related to the breeder program and the LMFBR from selected agencies of Government, representatives of industry, public groups, and others. The issues addressed include the Nation's need for energy, the electrical component thereof, the alternative fuels and available resources, and the merits or demerits of a commitment to the development of the breeder reactor as a partial solution to the projected electrical energy need. In all, 90 letters were dispatched and about 60 replies were received, representing all extremes of the spectrum of attitudes on the subject of the breeder reactor. This material was provided to all Committee members and has been made available to the public for inspection. It will also soon be available as a Committee print.

The Subcommittee has already held a series of briefings in public session concerning the history of the civilian nuclear power program, the uranium fuel cycle, the enriching process, the present status of civilian nuclear power and a description of the Clinch River Demonstration Plant.

Today's hearings mark the start of a new phase in the Subcommittee's activities. A series of six hearings will be held during June and early July which are structured on the basis of topics identified in the responses to the Subcommittee's April 11 letter to 90 organizations and individuals referred to above. Sessions will be held

on the subjects of Energy Trends; Alternate Energy Sources; Safety and Environmental Issues; Role of Converter and Breeder Reactors; Safeguards; and Cost/Benefit Analysis. In extending invitations to witnesses, we have determined to obtain oral testimony on all perspectives of the principal issues which we have identified for consideration, and to have competent witnesses on all subjects. These hearings will be followed by testimony to be presented by Dr. Robert Seamans, Administrator of the Energy Research and Development Administration early in July.

Today's session is on the subject of energy trends, and we are privileged to have with us Mr. Alan McGowan, President of the Scientists' Institute for Public Information (SIPI), Dr. John Holdren of the University of California, Berkeley, Dr. Bruce Netschert, Vice President of National Economics Research Institute and Mr. Roger LeGassie, Assistant Administrator for Planning and Analysis of ERDA. These speakers will cover energy growth rates and the total projected energy demand in the U.S. for the years 1985, 2000 and 2020; the effect of energy conservation and its limitations; the growth rate of electrical energy; and the significance of recent reductions in electrical energy growth rates.

SUMMARY

Mr. Alan McGowan, President of Scientists' Institute for Public Information, testified on future energy trends and in particular stated his opinion that the AEC (now ERDA) had justified breeder development by promoting inflated projections of growth in electrical demand. Among the points noted by Mr. McGowan that would lead to lower demand were variances in fertility rates which led to different population estimates in the years 1985 and 2000, the effect of price elasticity on electrical demand, and use of the relationship between GNP and energy demand. Also noted was the potential for reduction practices and the contribution of other energy alternates such as solar. Mr. McGowan also claimed that the high priority given to the breeder by the AEC was due in part to industry support since industry already has a large investment in nuclear technology.

During the question and answer period the following major points were noted:

When asked what should be done if the low demand estimates he was quoting were wrong, and that higher demands were realized, Mr. McGowan said he believed that other energy alternatives would be able to do the job. Based on further questions, he estimated that alternatives could contribute 2–5% to the electricity supply in 1985 and 25% in the year 2000. The question was asked on the cost of R & D and the capital costs to achieve these figures in energy supply. Only an estimate for R & D costs to 1985 were given—$1 billion. No estimates were available for 2000 or for capital costs for either year. Another question area dealt with development of the breeder and dependence on oil imports. Considering all the electrical demand estimates, high or low, dependence on foreign oil imports was still required. Mr. McGowan noted that none of his assumptions dealt with the availability of foreign oil.

The next speaker was Dr. Holdren of the University of California.

Dr. John Holdren focused his testimony largely on the effect that conservation measures could produce. He stated his belief that rapid growth in energy use fosters expensive mistakes and results in taking expensive gambles, that increases in energy may even do more harm than good, and that conservation of energy could mean doing better and not doing without. Other points noted by Dr. Holdren were that saving a barrel of oil is generally cheaper than producing a barrel, that less energy can mean more employment and that the link between energy and use and economic prosperity is not firm, but flexible.

A major portion of questions to Dr. Holdren dealt with his contention that less energy could mean more employment. Dr. Holdren's point was that if there were a movement away from energy intensive industries to labor intensive industries, employment would benefit. One question asked what would happen to the costs after the switch to the labor intensive industry occurred. Since labor was often a major cost, wouldn't prices then rise rapidly as labor costs rise? Also noted in the questions was that taken to the extreme, this approach would mean the U.S. would have all service-type industries and no manufacturing of goods. Dr. Holdren agreed there was a limit to this but pointed out that other countries like Sweden have a better ratio than the U.S. on per capita energy consumption, while still providing good services for their people.

Dr. Holdren's testimony was followed by that of Dr. Bruce Netschert of National Economic Research Associates, Inc., who reviewed the potential for energy conservation measures to affect energy demand. In his prepared remarks, Dr. Netschert defined conservation as the avoidance of economically avoidable

waste and indicated that price-elasticity will act to some extent to hold energy usage down, but noted that the operation of economic forces alone will not result in sufficient conservation. He also discussed the distinction between energy and electricity, noting that conservation of the former is not necessarily the same as conservation of the latter.

Dr. Netschert went on to describe the potential for conservation in the "management" of heat sources in industry, but added that, in contrast, the use of electricity for heating purposes offers little opportunity for conservation. The major opportunities lie in the direct use of fuels. In the residential sector, he noted there are fairly severe limits to what can be accomplished through voluntary action without the existence of clear emergency conditions. The propsects for further electricity conservation in the commercial sector were shown to be similar to those in the residential sector.

This presentation was concluded with the observation that conservation, in the absence of overriding emergency conditions, will have a relatively limited effect on the future growth in electricity use. On the other hand, if industry solves its fuels problem with greater rather than less electrification, growth rates in electricity in future years will exceed those of the past. Therefore, electricity may play a relatively larger role in the future total national energy picture. Dr. Netschert suggested under questioning that this point should be kept in mind by the Subcommittee in determining the need for the breeder.

The last witness of the day was Mr. Roger LeGassie, ERDA's Assistant Administrator for Planning and Analysis. Mr. LeGassie presented information on energy projections developed by ERDA earlier this year but not published, and summarized the low, moderate and high growth cases. The low growth case made maximum use of energy conservation and assumed a more austere life style. This high growth case presumed a return to low energy prices compared to prices of other commodities. Electricity demands for the three growth cases were also provided. Mr. LeGassie also noted that his projections covered a broad range that is representative of the forecasts produced by other groups. The last portion of his testimony covered the projections for the contribution to be provided by nuclear power. Estimates for low, moderate and high nuclear power growth were presented. The low growth case took a pessimistic view of industry's future success in coping with schedules and cost overrun problems. The high growth case assumed a favorable climate for nuclear plant construction and operation.

During questioning, Mr. LeGassie noted that ERDA was developing a revised set of energy electricity and nuclear power projections which would be submitted to Congress by June 30 as part of ERDA's comprehensive energy development plan. He concluded by indicating that the projections to be reported in that plan would be lower than those used in previous estimates.

From the information presented by the several speakers, it was clear that a wide range of energy and electricity demands can be postulated in future years depending on various assumptions of population factors, economic impacts, industrial growth, effects of conservation and other factors. The speakers themselves cautioned against the pitfalls of overestimating or underestimating future energy needs. The Subcommittee agrees and will now focus its attention on energy projections in the mid-range of those presented. In conjunction with information to be presented on the other issues relevant to the breeder, the Subcommittee will utilize these projections in proposing appropriate strategies for the development of energy sources.

Report of Subcommittee To Review Liquid Metal Fast Breeder Reactor

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Thursday, June 12, 1975

Mr. McCormack. Mr. Speaker, in continuance of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Subcommittee To Review the National Breeder Reactor Program, I have the following report:

Yesterday, the Subcommittee in open session received testimony from invited witnesses on the subject of alternate energy sources. During this session there was presentation and discussion of information pertaining to conventional energy sources, the potential of alternate energy technologies to meet energy demand requirements, their timing for possible introduction, their ability to provide large-scale electrical production capacity, and their principal limitations.

Testimony was presented by Dr. John Teem, Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems, Energy Research and Development Administration. His appearance was followed by a panel consisting of Dr. Allen Hammond, American Association for the Advancement of Science; Mr. Marc Messing, Environmental Policy Center; and Dr. Joseph Oxley, Battelle Memorial Institute. Each of these witnesses presented his testimony in turn and the entire panel was available for questioning by committee members.

I was pleased that Senators John V. Tunney and James L. Buckley, and Congressmen John B. Anderson, Manuel Lujan, Jr., and Frank Horton, were able to attend and participate in the questioning of the witnesses.

My opening remarks and a summary of the material presented and the ensuing discussion follow:

OPENING STATEMENT BY CHAIRMAN M'CORMACK

Today the Joint Committee's Special Subcommittee to Review the National Breeder Reactor Program holds its second session in a series of public hearings on the principal issues relative to this Nation's fast breeder reactor program and related matters.

Yesterday we received testimony on the subject of energy trends. We heard the views of invited witnesses concerning total energy and electrical energy needs throughout the remainder of this century. A wide spectrum of predictions was presented and the Subcommittee will now focus its attention on a bandwidth of energy and electrical demand predictions within the middle range of those presented. Our witnesses yesterday cautioned against the pitfalls of either overestimating or underestimating our true future energy needs.

It is apparent that plans to develop the necessary energy resources to meet our national needs must be agreed upon and the necessary development programs brought into being, or, existing ones accelerated, to assure that supply and demand requirements are joined, without undue burden upon the consumer and without an over-dependence on other nations for energy resources.

Today the Subcommittee will consider the subject of alternate energy sources. I am pleased that today's witnesses include Dr. Allen Hammond of the American Association for the Advancement of Science, Mr. Marc Messing of the Environmental Policy Center, Dr. John Teem, Assistant Administrator for Solar, Geo thermal and Advanced Energy Systems, Energy Research and Development Administration, and Dr. Joseph Oxley of Battelle Memorial Institute.

First we will hear from Dr. Teem and then I will ask that the three remaining witnesses come to the table simultaneously and we will hear them in turn.

Dr. Teem's testimony covered the potential energy sources of fusion, solar and geothermal. The goals he quoted for the solar program ranged from 5–13 quads by the year 2000. This is about 2–6% of the projected total energy requirements in that year. Dr. Teem noted that technical problems which still exist include unavailability of economic, highly reliable solar components and cost effective solar heating and cooling systems. Dr. Teem noted that a cost reduction of 2–3 orders of magnitude would be needed for photovoltaic solar systems to become cost effective. He felt that if the government could show that the R & D need for solar systems would be provided and could demonstrate the technical and economic viability of solar systems, industry would be willing to invest in these systems. Dr. Teem noted that it would be necessary to obtain public and private acceptance of legal and regulatory changes. Also, changes in land use patterns and potential effects on the environment must be better understood. The development of these solar systems and the other items above, are the areas, Dr. Teem stated, in which ERDA would be addressing its programs. With respect to geothermal energy, electrical generation using hot water or brine was noted as well as use of geopressurized formations and hot dry rock methods which can be used to heat injected water. The National Program goal noted was 20–30 GW by 1985–90. Some of the major hindrances noted by Dr. Teem were lack of assurance by utilities on profit production, technical problems with higher salinity resources and the unknown extent of the resources.

ERDA's goal for fusion power presented by Dr. Teem was for the demonstration of reliable and safe power by 1995–1997. The three principal approaches on fusion noted by Dr. Teem were magnetic confinement, high density closed systems and open systems (magnetic mirrors). Large scale commercialization was not seen before the end of the century. These projections for solar, geothermal and fusion would have the potential for providing approximately 1% of our energy needs by 1985 and 10% by the year 2000. Dr. Teem concluded by saying that he believed

that all energy options should be developed to the point that their economic and environmental cost benefit could be evaluated. Dr. Teem stated that this includes the development of the LMFBR.

During the question and answer period, considerable interest was expressed in whether or not the large amount of funding required for the breeder program would leave sufficient funds available to continue R & D on solar, geothermal and fusion energy at a sufficient pace. Dr. Teem replied that he anticipated sufficient funding would be available for all important programs, noting that additional funds had recently been provided for the alternate systems by the Congress. He reviewed the funding history of these programs and concluded that continued R & D on the breeder need not jeopardize other technologies. In response to questions on whether we should concentrate on solar energy and fusion, and forego the breeder, Dr. Teem noted the former technologies have good potential for the long term, but that we need to develop all promising options now, including the LMFBR. He did note, however, that it is premature to commit now to breeder commercialization, and suggested additional R & D would be needed before that decision can be made. With regard to the alternate technologies, Dr. Teem also replied to questions on their relative environmental impact as opposed to the breeder, and agreed that the figures presented on their potential contribution to total energy needs by the year 2020 showed that fusion, for example, would provide only a few percent of our electric power. However, he noted that proponents of the alternate technologies believe that greater contributions can be made.

The remaining three witnesses appeared as a panel, each covering their prepared remarks before addressing questions. Dr. Hammond's testimony covered the potential use of coal, solar and geothermal energy in meeting future energy needs. Dr. Hammond noted his belief that the main energy sources used by utilities in the remainder of this century would be coal, with pollution clean-up and improved methods of combustion, and light water and high temperature gas-cooled reactors. Dr. Hammond urged acceleration of funding for alternate energy sources and as rapid development as possible of these technologies. It was noted by the Subcommittee that substantial increases in the funding level, year by year, had taken place for these energy sources, and that funds above that requested by ERDA had been placed in the ERDA budget by the Congress. Dr. Hammond stated that one of the more promising of the solar options, the photovoltaic cell, would have to be reduced in cost on the order of one hundred-fold to make it competitive with other energy sources. However, it was his contention that this could be done with mass production and with application of the innovative techniques of the electronics industry. Dr. Hammond concluded with a summary of the potential for geothermal energy.

Mr. Messing summarized his views on energy trends before going to the discussion of alternate energy sources. His projection of energy consumption in the year 2000 was 202 QBTU. On solar energy, Mr. Messing presented his information that a substantial portion of electrical energy that is projected to be supplied by nuclear power in the year 2000 could be replaced by solar energy.

The value quoted was 30%. He also stated that when one considers displacement of electricity and gas, that solar energy could contribute up to 10% of the energy requirements in the year 2000. Based on questioning of Mr. Messing and other witnesses, a consensus was obtained that a few percent was a more reasonable estimate. Mr. Messing concluded by noting the decreasing cost that would be realized for photovoltaic solar energy as mass production is achieved, thus making it more competitive with conventional sources. Dr. Teem had noted that a factor of 100–1000 cost reduction was needed; Dr. Hammond had quoted a reduction factor of 100.

Dr. Oxley's prepared remarks addressed technologies associated with production and use of liquid fuel from coal or shale, refined coals, gases manufactured from coals and waste utilization as well as the energy sources of solar and geothermal. Dr. Oxley noted that there would be a shift in industry back to coal and the use of electricity, supplied by a central power station. He urged that coal use be limited to the degree possible since it was an exhaustible resource and is needed as a raw material in various industries such as chemical production. He further noted that while use of manufactured gas would increase, its cost would prohibit its use for central station power production of electricity. Dr. Oxley concluded that central station electricity at the turn of the century will primarily be coal and nuclear with some contribution from geothermal and increasing attention to high-yield agricultural crops.

The prepared discussions of these three speakers were followed by a question and answer period. Major points are noted below.

The Subcommittee questioned Dr. Hammond's statements that funding for the LMFBR and alternate energy sources should be more equal. They noted that the LMFBR was in the demonstration phase, which was a higher cost-intensive phase, whereas alternate energy sources such as solar energy were still dealing with more basic technology. In subsequent discussions, Dr. Hammond agreed that development of the breeder should continue but that the schedule for commercialization and the role of the Clinch River plant were items of concern. The committee noted that there was no need for making a decision on commercialization now.

As for the Clinch River plant, committee members cited the light water reactor experience in taking approximately 25 years to reach commercialization, and therefore, suggested that for the breeder to contribute significantly by the year 2000, the demonstration plant needed to be pursued now. At a later point in the discussion, Dr. Hammond noted the priority that is still needed to get public acceptance of the light water reactor. Members of the subcommittee agreed and emphasized to Dr. Hammond the role he and other persons involved in writing magazine and news articles have in presenting a balanced picture to the public.

One of the questions to Mr. Messing dealt with the cost of solar power. Mr. Messing acknowledged that retrofit of a house would not be cheap, but also noted that with the high cost of utility bills, if solar power were available, money not spent on utility bills could go toward paying for installation of the solar power system. As perspective, the subcommittee noted that the overall contribution to the energy supply due to solar heating and cooling would be about a few percent of our energy usage by the year 2000.

Although the four witnesses presented a variety of views on the promises and limitations of alternate technologies, a consensus did become evident on the breeder program. The witnesses all agreed that the breeder was necessary, or at least that R&D on the breeder should still be pursued at this time. Questions were raised, however, on whether the approach being taken on breeder development was the right one. Generally, several witnesses questioned whether the design and timing of the Clinch River Breeder Reactor are optimal. It was also noted that the breeder's primary contribution to energy requirements would not occur until after the turn of the century, and that a decision or, commercialization of the breeder did not have to be made at the present time. These questions will be examined further by the Subcommittee in a forthcoming hearing and in the Subcommittee's continuing deliberation on the LMFBR Program.

Meetings of the Subcommittee To Review the Nuclear Breeder Program

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Monday, June 16, 1975

Mr. McCormack. Mr. Speaker, tomorrow at 2 p.m., the Joint Committee's Subcommittee to Review the National Breeder Reactor Program resumes public hearings in room S–407 of the Capitol. Tomorrow's session will focus on safety and environmental issues.

In each of these sessions, we have invited witnesses, with a view toward obtaining testimony both pro and con on the issues. I regret to report that for this forthcoming session none of the witnesses who in the past have been critical of the nuclear program have accepted our invitation to testify. In particular, the Union of Concerned Scientists, whose principal spokesmen are Dr. Henry Kendall and Mr. Dan Ford, choose not to testify. Dr. Arthur Tamplin, Natural Resources Defense Council, was invited, but he is overseas on extended business. An invitation was extended last week to Dr. Donald Geesamen, but he declied on the basis of inadequate time to prepare. Sheldon Novick of Environment magazine was also invited, but declined for the same reason. I should also mention that Friends of Earth specifically requested an opportunity to testify, but an invitation was extended to them, it was declined.

In order that the committee members and the audience at tomorrow's hearings will be able to hear the claims and allegations of those who have been critical of the program, I have asked Dr. Warren Donnelly of the Congressional Research Service to begin the session with an objective résumé of these claims and allegations, taken from testimony and public statements of qualified spokesmen for antinuclear groups. We will then hear presentations on safety and environmental

problems from Dr. David Rose of MIT, Dr. Chet Richmond of Holifield National Laboratory, and Dr. Bernie Cohen of the University of Pittsburgh. The committee members will have an opportunity for questions and discussion.

Mr. Speaker, I would also like to announce that it has become necessary to reschedule our June 19 subcommittee session on the subject of Safeguards by moving it to Wednesday, June 18, at 2 p.m.

REPORT OF SUBCOMMITTEE TO REVIEW LIQUID METAL FAST BREEDER REACTOR

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Thursday, June 19, 1975

Mr. McCORMACK. Mr. Speaker, in continuance of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Subcommittee to Review the National Breeder Reactor Program, I have the following report.

On Tuesday, June 17, the subcommittee in open session received testimony from invited witnesses on the subject of safety and environmental issues. During this session, there was presentation and discussion of information pertaining to the disposal of nuclear wastes, the problem of plutonium toxicity, the safety of breeder reactors, the relative safety and environmental aspects of coal-fired and nuclear power plants, and related environmental concerns regarding the use of breeder reactors. Testimony was presented by Dr. Warren Donnelly of the Congressional Research Service, Dr. David Rose of the Massachusetts Institute of Technology, Dr. Chester Richmond of Holifield National Laboratory, and Dr. Bernard Cohen of the University of Pittsburgh. I was pleased that Representatives John B. Anderson, Manuel Lujan, Jr., and Teno Roncalio were able to attend and participate in the questioning of the witnesses.

My opening remarks and a summary of the material presented and the ensuing discussion follow:

OPENING STATEMENT BY HON. MIKE M'CORMACK

Today the Joint Committee's Subcommittee to Review the National Breeder Reactor Program will receive testimony on the subject of safety and environmental issues.

In each of the Subcommittee sessions, we have invited witnesses, with a view toward obtaining testimony both pro and con on the issues. I regret to report that for today's session none of the witnesses, who in the past have been critical of the nuclear program, have accepted our invitation to testify. In particular, the Union of Concerned Scientists, whose principal spokesmen are Dr. Henry Kendall and Dan Ford, did not choose to testify. Dr. Arthur Tamplin, Natural Resources Defense Council, was invited, but he is overseas on extended business. An invitation was extended last week to Dr. Donald Geesamen, but he declined on the basis of inadequate time to prepare. Sheldon Novick of Environment Magazine was also invited, but declined for the same reason. I should also mention that Friends of the Earth requested an opportunity to testify, an invitation was extended but it was declined.

In order that the Committee members and the audience at today's hearing will have identified for them the claims and allegations of those who have been critical of the program, I have asked Dr. Warren Donnelly of the Congressional Research Service to begin the session with an objective listing of the issues as he understands them from his study of this subject area.

We will then hear presentation from Dr. David Rose of MIT, Dr. Chet Richmond of Holifield National Laboratory, and Dr. Bernie Cohen of the University of Pittsburgh and have an opportunity for questions and discussion.

I would also like to announce that it has become necessary to reschedule our June 19 Subcommittee session on the subject of Safeguards by moving it to tomorrow, Wednesday, June 18 at 2:00 p.m. At that time, we will hear testimony presented by Dr. Ted Taylor (International Research and Technology Corporation), Dr. Orval Jones of Sandia Laboratories, and Major General Edward Giller of Energy Research and Development Administration.

Dr. Donnelly, you may proceed.

SUMMARY

Dr. Warren Donnelly of the Congressional Research Service provided a review of the safety and environmental issues that have been raised in criticism of the breeder program. Dr. Donnelly noted that his testimony was based in part on information contained in response to a letter sent by the Subcommittee Chairman to about 90 government agencies, industrial firms, public interest groups and individuals. This letter asked 17 major questions on energy and nuclear power, and also examined the topics that would be discussed in his testimony.

Dr. Donnelly reported that the issues raised in criticism of the breeder program can be classified under the heading of safety, safeguards and environmental effects. Of these, the principal concern has been one of safety, specifically, that the probability of a catastrophic release of radioactive materials through the occurrence of a core disruptive accident or by intention is so high that the breeder should not be used as a source of electrical energy. Critics have stated that LMFBR's can explode with forces severe enough to rupture the protective enclosures. They do not believe that the safety analyses performed in reactor design or the protective features provided to prevent accidents or mitigate their consequences are sufficiently reliable.

The subject of safeguards was also cited as having been noted by some as a major reason for not developing a breeder economy.

Dr. Donnelly reported that the concerns in this area are the possibility that terrorists, political extremists, or criminals might successfully steal nuclear materials and use them in a crude bomb or radiological weapon, and that the prospects of sabotage of nuclear facilities with the resulting release of radioactive materials also increase as a breeder economy comes into widescale use. The costs of a safeguards program and its possible impact on civil liberties were also noted.

Dr. Donnelly reported that the environmental issues that have been raised against breeder reactors include concern over the toxic effects of plutonium on health and safety, the need for perpetual safe management of radioactive wastes, and the effects of small routine releases of radioactive wastes throughout the breeder's fuel cycle. A lesser level of attention has been given to waste heat and the impacts upon land and water use.

Other issues noted by Dr. Donnelly as having been raised by breeder opponents, although not necessarily safety or environmental concerns, include:

1. Insufficient technical promise, in that the anticipated fuel doubling time may be longer than estimated;
2. The possibility that sufficient uranium reserves may exist in the U.S. as to delay or abandon the need for the breeder;
3. The argument that breeder economics are unfavorable:
4. The suggestion that more desirable alternative energy sources can be developed instead of the breeder;
5. The suggestion that energy demand levels in the future may be lower than anticipated, thereby eliminating the need for the breeder; and
6. The contention that breeder reliability may be insufficient to warrant its use as an important source of electrical power.

Dr. Donnelly concluded his remarks by listing some of the organizations that have espoused the above views and by noting some of the forums in which those views have been expressed.

Dr. Richmond's testimony focused on the potential health effects of plutonium and in particular on the "hot particle" issue. He noted the basis for the Natural Resources Defense Council's (NRDC) contention that the hazard from plutonium inhalation was much greater than assumed by various government agencies and also noted NRDC's proposal to reduce the exposure limit by a factor of 100,000. Dr. Richmond presented evidence and the results of much research in this area that does not support NRDC's claim. Dr. Richmond also quoted assessments from foreign medical research groups that refuted the NRDC claim of a too-high dose limit. Other evidence provided by Dr. Richmond was the experience of the 25 persons involved in the Manhattan Project 30 years ago who received overexposures to plutonium. The hot particle theory would predict a total of 1,000 to 10,000 lung cancers among the group. Dr. Richmond stated that none had developed cancer.

The world-wide exposure from plutonium dispersed from atomic weapons tests was also noted as further evidence that the plutonium risk was being grossly overstated in the hot particle theory. Dr. Richmond concluded with a word of caution about the misuse of risk evaluations using the manrem approach. He said that this concept had been sufficiently abused that the National Council on

Radiation Protection (NCRP) chose to issue a statement noting a word of caution about the use of upper limit estimates of cancer risk at low exposure levels derived by extrapolation of data obtained from high dose and high dose rate experiments.

Dr. Rose's testimony centered around the environmental impact associated with the use of nuclear fuel and coal to produce electricity. In his initial remarks, Dr. Rose summarized the potential savings in energy use due to conservation and the long-term potential of fusion and solar power. With respect to nuclear power, Dr. Rose noted briefly several of the safety issues currently being investigated. Reference was made to the WASH-1400 report on light water reactor (LWR) risk assessment and he suggested that a similar assessment should be done for the LMFBR. Dr. Rose commented, however, that in his opinion, the LMFBR accident sequence will add little to the LMFBR hazard if one applies similar methodology to the risk analysis as was used for the LWR. Several comments were made on the potential for a nuclear excursion and what the upper limit for this type of accident might be.

Dr. Rose stated his belief that storage of nuclear wastes would be possible technically and that the real question was more a moral one, viz. should we obtain benefits from an energy source now for which future generations will have to pay the costs. Under questioning, Dr. Rose stated that the costs would not be that large and that the benefit to cost ratio justified this approach. Several methods of waste disposal were presented including burial in deep geologic beds and the use of advanced separation techniques for very long lived isotopes, such that recycling them into the reactor could be accomplished rather than burial. He concluded this portion of his presentation with the statement that the nuclear waste problem has been overemphasized by critics and misassessed by the AEC and contractors.

With respect to the hazards related to nuclear power, Dr. Rose noted that the greatest contributor to fatalities was from mining and milling of uranium ore. The reactor accident hazard was noted to contribute only 1/100 of the hazard from other sources.

The environmental picture for coal compared to nuclear was stated by Dr. Rose as being "more bleak." He noted that the present welfare payments to miners having black lung disease amounted to over 1 billion dollars per year. Also of concern was the "greenhouse effect" or the building up of CO_2 in the atmosphere, which will result in an overall warming trend of the earth's atmosphere.

Dr. Rose spoke to the lack of data on the hazards of sulphur oxide and nitrogen oxides. Dr. Rose closed his remarks with the interesting observation that the public in general had come to accept the social costs associated with the use of coal even though they are larger than those from nuclear power. One possible reason given by Dr. Rose was that the Government had spent considerable funds in attempting to measure public health costs associated with nuclear power whereas until recently, very little had been done to measure the similar hazards of fossil fuel power. Dr. Rose concluded from the evidence to date that the environmental comparison favors nuclear power.

Dr. Cohen's remarks centered around the issue of nuclear wastes. While no single one method has been chosen, Dr. Cohen expressed his belief that deep burial of wastes will be the eventual method used. Dr. Cohen compared the ingestion of plutonium to arsenic trioxide (a widely used pesticide in this country) and observed that plutonium is 50 times less poisonous per pound. In addition, he pointed out that annually we import 10 times more arsenic trioxide than the quantity of nuclear wastes that would remain after 500 years decay.

Dr. Cohen explained that wastes buried in deep geologic beds, even if exposed to water, would be leached very slowly; water itself moves very slowly through aquifers taking typically 1000 years to reach the surface. Wastes would move even more slowly due to the ion exchange process.

Dr. Cohen compared the risk of deep buried wastes to the exposure risk from radiation naturally occurring in the ground and concluded that wastes generated over a million years would still only contribute 0.4 deaths per year. This number was considered by Dr. Cohen also to be an upper limit.

The final issue discussed by Dr. Cohen was the burden we would place on future generations in caring for these wastes. Dr. Cohen noted that no care after burial was really needed, but if a country desired to watch the wastes, one person would have to travel around a 200 square mile area seeing that no one was drilling for oil or mining salt and collecting water samples every few weeks. This would mean, Dr. Cohen stated, that the burden for future generations would be a part time

job for one person. Dr. Cohen concluded by comparing this insignificant burden to the burden we are placing on future generations by leaving them with no oil, no gas, and depleted hydrocarbons that are used as feed stocks for plastics, chemicals, etc.

A question and answer period of all the witnesses followed the prepared remarks. Dr. Cohen was asked what would happen if the containers in which wastes were buried suffered extensive corrosion. Dr. Cohen reported that in his analysis model, he didn't take any credit for the containers whatsoever. Dr. Rose was asked to amplify on remarks attributed to him that the Clinch River Breeder Reactor (CRBR) demonstration plant be delayed. Dr. Rose stated that there is no doubt that the breeder is needed. However, he believed that a study needs to be completed to see if there should be improvements in the CRBR plant design. He said he believes there could be a year or so delay in CRBR without too much disruption, but that a close option was to proceed now with the CRBR but still do the study. The management of CRBR especially, its top heavy nature, was noted as a particular problem by Dr. Rose.

Dr. Richmond was questioned on the exposures from normal power plant operations. He noted that such exposures were well below natural background and somewhat similar to the exposure received from flying cross country in an airplane. Dr. Cohen noted that if one was considering moving away from a nuclear power plant, that even using the critics' numbers of risk, if one were to move more than 2 miles and thus increased his daily commuting distance to work by that amount, the additional risk of injury and death would be greater than staying next to the power plant.

In conclusion, this hearing served to highlight the several safety and environmental issues that have been raised regarding the breeder reactor, including presentation of information on both sides of each issue. These matters will be considered by the Subcommittee in its continuing review of the national breeder program.

Report of Subcommittee to Review Liquid Metal Fast Breeder Reactor

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Thursday, June 19, 1975

Mr. McCormack. Mr. Speaker, in continuance of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Subcommittee to Review the National Breeder Reactor Program, I have the following report:

Yesterday, the subcommittee in open session received testimony from invited witnesses on the subject of safeguards. During this session, there was presentation and discussion of information pertaining to the physical security measures designed to prevent the theft of nuclear materials or the sabotage of nuclear facilities, the costs of providing an effective safeguards program, the possible impacts on civil liberties of the safeguards program, and the Energy Research and Development Administration's program to develop safeguards commensurate with the eventual commercial use of breeder reactors.

Testimony was presented by Dr. Theodore Taylor of International Research and Technology Corp., Dr. Orval E. Jones of Sandia Laboratories, and Mr. Robert Tharp—for Maj. Gen. Edward B. Giller, USAF (Ret.)—of the Energy Research and Development Administration. I was pleased that Senator Clifford P. Case, Congressmen John B. Anderson, Manuel Lujan, Jr., and Andrew Hinshaw were able to attend and participate in the questioning of the witnesses.

Opening remarks for the session and a summary of the material presented and the ensuing discussion follow:

OPENING STATEMENT BY THE CHAIRMAN—JUNE 18, 1975

Today the Joint Committee's Subcommittee to Review the National Breeder Reactor Program will receive testimony on the subject of safeguards.

This session was initially scheduled to be held tomorrow, June 19th, but it became necessary for the Subcommittee to reschedule it for today.

I would like to announce that one of the invited witnesses, Mr. Gus Speth, of the Natural Resources Defense Council, was unable to participate because of a conflict, but has submitted a statement for the record expressing his views. Copies of this statement have already been distributed to all Committee members and subject to objection will be included in the record of these hearings.

Today we will receive oral testimony from Dr. Ted Taylor (International Research and Technology Corporation, Dr. Orval Jones of Sandia Laboratories, and Major General Edward B. Giller of the Energy Research and Development Administration.

SUMMARY

Dr. Taylor opened his remarks by restating his position that if one had 10 kilograms or so of plutonium, it would be conceivable that a group of terrorists or a person working alone could design and build a crude fission bomb. He noted that the only amount of material required was only a small fraction of the present yearly amount of plutonium produced in the U.S. (5000 kg/yr.) Dr. Taylor noted, however, that there are no reprocessing plants currently in operation to separate plutonium from fission products and, therefore, the plutonium is in a very unusable form. He further stated that his remarks about designing and building a weapon assumed that the plutonium was available. This, Dr. Taylor stated, was the area where significant safeguard actions can be taken and which he believed could be successful in reducing the risk of theft and diversion to an acceptably low level. Dr. Taylor said that safeguards was an issue even without the breeder since LWR's also produce significant quantities of plutonium.

Dr. Taylor concluded with a few remarks on the potential costs of the safeguards programs. He said if it is assumed that extremely stringent safeguard measures are applied to an LMFBR fuel cycle module of 80,000 MWe capacity, the safeguard costs would represent only about a 1.4% increase in the cost of electricity.

Dr. Jones testified on various physical security aspects of the safeguard question. He stated that safeguard risks can be viewed as the product of four multiplicative factors: (1) the frequency of attempted diversion or sabotage, (2) the likelihood of success, (3) the likelihood that the malevolent act will harm the public, and (4) the cost of such malevolent acts. ERDA is developing a balanced safeguards program in these four areas, Dr. Jones stated. A summary was then provided of various approaches being used. For transportation applications these included overview descriptions of safe-secure trailers, special escort vehicles and a nationwide communications system. The approach to security for permanent facilities using both passive and active deterrent techniques was described. Dr. Jones noted that many of the techniques being used or considered had come from military experience in shipping special nuclear material, but that much of it was also recent innovative ideas applicable to the civilian program itself.

Mr. Tharp (speaking from testimony prepared for delivery by Gen. Giller) summarized the history of the safeguards and security program that has been in use for fissionable materials since the mid-1940's. He noted how the upsurge of worldwide terrorism in the 1970's has pointed up the need to guard against possible attacks on nuclear facilities. Mr. Tharp reported that the general objective of nuclear materials safeguards is to prevent successful malevolent acts involving nuclear materials and facilities. The degree to which the general safeguards objective is met is measured in terms of protection of the public against risk of death, injury and property damage potentially arising from these acts. It was stated that this objective can be met through an indepth approach consisting of reducing the frequency of attempts to produce societal consequences, reducing the likelihood of adversary success when an attempt is made, and reducing the consequences of a successful act.

Mr. Tharp reviewed the operating experience in the safeguarding of nuclear material of date, which has not resulted in any harmful effects on the environment or populace. He discussed how this experience would form the basis for future safeguards efforts. Mr. Tharp also reviewed certain elements of the fuel cycle, such as transportation, which has particular importance as the most difficult portion of the fuel cycle to safeguard. The means by which existing ERDA safeguards programs are being expanded to meet nuclear fuel cycle needs were also examined. The use of material control and accountability procedures as well as physical security measures were examined in this regard.

Finally, Mr. Tharp reviewed the potential of nuclear energy parks (colocation of facilities) as a means of alleviating the safeguards problem. Various forms of colocation (e.g., reactors dispersed, but reprocessing and refabrication facilities colocated) were examined and the general safeguards benefits reviewed. This concept is still under study.

In conclusion, Mr. Tharp contended that ERDA's long experience in handling and transporting large quantities of plutonium, coupled with a viable R & D program, ensures effective safeguards for all future fuel cycles. He reported that the financial costs and impacts on civil liberties would not be overriding, and that

there is no safeguards related reason to delay the further development of the LMFBR.

A question and answer period followed the presentations. One of the main concerns in the safeguards issue raised by anti-nuclear groups has been that the U.S. would have to create a virtual police state to protect the plutonium. The witnesses each presented facts to show this was not the case and that this claim by critics was an emotional appeal to raise doubts in the mind of the public. It was stated that for a fuel cycle involved in the production of 80,000 MWe, there would be only 1400–1500 people involved in the security effort. Dr. Taylor compared this to the some 600,000 persons throughout the U.S. presently engaged in police activities. The conclusion was that there was no basis for the claim of a police state.

Another criticism often noted was that civil liberties of a major portion of our population would be infringed due to security clearances that would be required of workers in nuclear facilities. Gen. Giller noted that all the people that would be involved in nuclear power production who would need clearances would be a very small fraction of those needing clearances in ERDA, for example, and when one considers DOD, the number is small, indeed. Dr. Taylor noted that a reprocessing plant like Barnwell which is to be able to reprocess a significant amount of the fuel in the future, will employ only 300 people.

The question was asked of Dr. Jones if the special trucks being used for nuclear material shipments could be picked up by a helicopter—one, say, stolen from the military. Dr. Jones said it was possible, but besides the military efforts to recover the helicopter, the communications system in the truck would call for response action by recovery teams to be taken immediately. The question was also asked if high-energy lasers had been considered as a means for getting into the special trucks. It was suggested this be checked.

Dr. Taylor was asked what the hazard would be from a criticality accident during assembly of a homemade bomb. He stated it would be very risky but not so great as to be a deterrent.

A question was raised regarding the confidence one should have in the utilities, carriers, reprocessers, etc., in complying with all the government regulations and in one's ability to enforce the regulations. The numerous incidents of noncompliance in common carrier shipments of radioactive material were noted. Gen. Giller pointed out that shipments of radioactive material on a common carrier represent only a part of their business, whereas shipments of the type described for plutonium would involve trained personnel whose sole job was to safely transport this material.

Dr. Taylor commented on "spiking" of the fuel as a deterrent means. He felt that this approach would not come into use. He stated that the use of fission products as a means of spiking fuel and inhibiting its reprocessing would not be successful as the fission products could be separated out rather readily by chemical means. From a transportation point of view, Dr. Taylor, stated that the shielding needed to make the shipment safe in normal conditions would add such weight that the heavy cask would be more of a deterrent than the radiation. In addition, Dr. Taylor noted that the cost of reprocessing would be increased drastically.

It was the general conclusion of this session that while the safeguards question would have to continue to receive proper attention, it did not present any basis for failing to continue the development of the breeder program.

Report of Subcommittee to Review Liquid Metal Fast Breeder Reactor

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Wednesday, June 25, 1975

Mr. McCormack. Mr. Speaker, in continuance of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Subcommittee to Review the National Breeder Reactor Program, I have the following report:

Yesterday, the subcommittee in open session received testimony from invited witnesses on the subject of the role of converter and breeder reactors, and on the role of the LMFBR and the LMFBR Demonstration Plant—Clinch River Breeder Reactor. During this session, there was presentation and discussion of information on our energy usage patterns, available energy sources, characteristics of breeder reactors, objections to the use of breeder reactors, and possible sub-

stitute reactor technologies. Possible changes in the U.S. breeder program were also discussed, including an accelerated development of LMFBR technology, the construction of additional prototype plants, and modifications to the licensing process.

Testimony was presented by Dr. Dean Abrahamson, professor of public affairs at the University of Minnesota and a member of the Board of Trustees of the Natural Resources Defense Council; Mr. John Simpson of Westinghouse Electric Corp.; Dr. Hans Bethe of Cornell University; and Mr. Leonard Koch of Illinois Power Co.

I was pleased that Senators John V. Tunney and Clifford P. Case, and Congressmen John B. Anderson, Manuel Lujan, Frank Horton, and Andrew J. Hinshaw were able to attend and participate in the questioning of the witnesses.

My opening remarks and a summary of the material presented and the ensuing discussion follow:

OPENING STATEMENT BY THE CHAIRMAN

This afternoon the Joint Committee's Special Subcommittee to Review the National Breeder Reactor Program resume its public hearings. The focus of today's hearings is on the role of converter and breeder reactors, and the role of the LMFBR and the LMFBR demonstration plant. This session will cover the use of converter and breeder reactors in conserving fuel resources, estimates of U.S. uranium and thorium resources; the priority between the LMFBR and other breeder concepts and the role of the LMFBR Demonstration plant.

We are pleased to have before us today, Dr. Dean Abrahamson of the Natural Resources Defense Council, Inc.; Dr. Hans Bethe, Nobel laureate, from Cornell University; Mr. John Simpson of the Westinghouse Electric Corporation; and Mr. Leonard Koch of Illinois Power Company.

Dr. Barry Smernoff of the Hudson Institute requested the opportunity to testify at this session, but the Subcommittee believed that it would be unwise to add another witness because of time limitations. Dr. Smernoff has submitted a written statement for inclusion in the record and subject to objection by any member, it will be made a part of this record.

Dr. Abrahamson, we are pleased to have you here with us today and you may proceed.

SUMMARY

Dr. Abrahamson noted at the outset of his testimony that nuclear reactors unavoidably produce large quantities of dangerous radioactive material and materials that might be used in the fabrication of nuclear weapons. He reported this results in several hazards that make nuclear fission unacceptable: First, the potential for release of radioactive materials through accident or malice; second, the problem of radioactive waste disposal; third, the proliferation of nuclear weapons; fourth, the potential for terrorist activities through use of stolen plutonium; and fifth, the social impacts of safeguards measures. Only two of these hazards, according to Dr. Abrahamson, are resolvable by technical means—nuclear accidents and waste disposal. Economic problems also impact adversely on the use of nuclear power.

Dr. Abrahamson discussed the national debate now taking place over nuclear fission, and suggested it should have occurred earlier. He indicated that if the use of nuclear fission should be reaffirmed, the following minimum conditions should be met: First, the siting of all nuclear power facilities in nuclear reservations—sometimes called nuclear parks or nuclear energy centers—with fuel fabrication plants, reactors, and waste management facilities on the same site; second, effective international control, and perhaps ownership, of all special nuclear materials; third, elimination of the Price-Anderson Act or its equivalent; and fourth, no separation of plutonium from the spent fuel and therefore no recycle.

Dr. Abrahamson went on to state that the use of breeder reactors in his view is also unacceptable, but that if they should be employed, the same conditions as above should be imposed—except that plutonium recycle would be an integral part of breeder operation.

Dr. Abrahamson reiterated the views of Dr. Thomas Cochran on the LMFBR, with which he concurs: Delay of the commercial component by a decade, recast the LMFBR effort on a lower priority program centered on the fast flux test facility, and cancellation of plans for the Clinch River breeder reactor. These steps, according to Dr. Abrahamson, would free up funds for accelerated development of solar and geothermal power, fusion, conservation, et cetera. Also during this delay period, additional needed safety information on LMFBR could be obtained.

Mr. Simpson reviewed the role of energy in our economy, and discussed the energy sources that are being used or are projected for use by the year 2000. He reported that the only option available to sustain a healthy economy is increased reliance on electricity from coal and uranium, with rapid development of the breeder necessary for a guaranteed continuance of low-cost electricity. Mr. Simpson reviewed the use of nuclear power in this country to date, including the fuel savings accrued from reduced usage of oil and gas. He showed that nuclear fuel resources were limited, and cited the priority that has been placed on breeder development to extend the use of nuclear fuel. He reported that the culminating task in the development of the LMFBR is to improve the reliability, licensability, and economics through the demonstration plant program. Mr. Simpson described various important elements of the Clinch River breeder reactor—demonstration plant—including its place in the technological development program, its utility backing, its licensability aspects, and its present design status. He concluded by stating that its schedule is consistent with the goal of commercial LMFBR operation in the early 1990's, and noted that if the LMFBR is needed to meet energy demands, but not developed, the Nation's problem may be one of electrical energy shortfall greater than anything yet experienced in this country.

Dr. Bethe began his testimony by observing that it is essential we make full use of the "nuclear option." He then reviewed the fuel utilization aspects of present day light water reactors, and noted that the President's program calls for the construction of 200 reactors between now and 1985. Even with a "low" energy use pattern, all the high grade uranium ore in the United States will be committed by about 1992. Dr. Bethe indicated this is earlier than the breeder can be ready for full commercial exploitation, and therefore, he concludes the breeder is already too late, and any further delay will be very costly.

Dr. Bethe then reviewed the advantages of the breeder, including its minimal requirement for uranium, its use of plutonium produced in light water reactors, its low cost of chemical processing per gram of uranium burned—as compared to LWR's—and its demonstrated feasibility. He noted that all countries engaged in such a program have chosen the LMFBR due to its technical advantages. Dr. Bethe next examined the objections that have been raised against breeder reactors, citing high costs, hazards of plutonium diversion, and the potential for nuclear accidents. With regard to costs, he suggested that the high cost listed for the Clinch River breeder reactor is misleading due to inflation, the inclusion of development costs, and to its being a first of a kind plant. He also discussed projected cost differences between later breeder reactors and LWR's, and concluded that when the costs of future higher priced uranium are taken into account, breeder reactors obtain a net cost advantage per unit of electricity produced over LWR's.

Dr. Bethe concluded by suggesting several substitutes for the LMFBR if it should not receive a clear go-ahead. These substitutes are in various stages of development. They are the molten salt breeder reactor, the light water breeder reactor, the high temperature gas-cooled reactor, and the CANDU reactor. He believes it would be worthwhile for the United States to go into partnership with Canada in developing an advanced CANDU reactor. His main recommendation, however, is rapid development of the fast breeder.

Mr. Leonard Koch testified that nuclear power is the only demonstrated new technology which can satisfy a significant fraction of our energy demand during the balance of this century, and noted that breeder reactors can extend that capability for several more centuries. He reviewed the nuclear fuel situation for breeder reactors and cited its great potential. He expressed the opinion that the U.S. program for development of commercial breeders has not been consistent with our need for new energy sources or with the breeder's potential.

Mr. Koch reviewed foreign progress in LMFBR development and said it will be necessary for the subcommittee to compare the U.S. program to those foreign efforts. He also believes the evaluation should consider the use of other energy sources in place of the breeder, and the forced reduction of energy use in the United States. Mr. Koch's opinions on these matters are: First, there are no demonstrated alternate energy sources with the potential capability of the breeder; second, the concept of U.S. dependence on foreign breeder technology is unacceptable; and third, conservation, while desirable, is not an alternative to the breeder.

In view of these considerations, Mr. Koch believes the U.S. breeder program should be accelerated and given more positive direction. He feels our primary need is design, construction and operation of large breeder reactor central power stations, and that we should be proceeding with more than one prototype or

"near commercial" station. He believes we should classify the breeder program as urgent, abbreviate the licensing process, and omit the public hearing procedure. The only hearings on the breeder should be held by the Congress. With these actions, Mr. Koch believes a more optimum program with greater likelihood of providing timely commercial breeders will ensue.

A question and answer period followed the presentations. Mr. Simpson was asked to comment on the suggestion made at an earlier hearing held by the subcommittee that the Clinch River Breeder Reactor design is outdated and should be replaced by a more advanced design. Mr. Simpson replied that one can always claim that the design of a complex and lengthy project is "old" sometime after it is first conceived, but noted the CRBR was not designed as long ago as implied by critics. He stated the design was revised somewhat earlier this year, that it is a reasonable extension of the Fast Flux Test Facility and properly relies on that technology, and stated that a new design started today would take several years to complete, after which time that design could be accused of being outdated.

Mr. Koch was asked to clarify his objection to foreign technology. He said his objection was not to the technology itself but to the reliance on foreign technology and supply which some people had suggested. Mr. Simpson, in response to a question on whether Westinghouse could manufacture a breeder of foreign design, noted that foreign plants could not meet U.S. licensing criteria in that they did not have containment buildings and other necessary design features.

Dr. Abrahamson was asked to expand on his view that additional reactors should not be built. Dr. Abrahamson replied that were it not for various political realities, he would like to see all reactors shut down. An alternative would be to continue operating existing reactors only, but build no more. Even if the four conditions noted in his testimony were met, he would prefer no further reactors be built.

The issue of eliminating licensing hearings as suggested by Mr. Koch was examined. Mr. Koch replied that hearings in the past have caused delays, and noted these could lead to exhaustion of our uranium supply. Mr. Simpson, however, added that the utility industry has adjusted to these delays, and now orders new plants earlier. Dr. Abrahamson stated that delays are not necessarily bureaucratic in nature, but were instead evidence that nuclear technology is premature. Mr. McCormack discussed a case where delays were caused by intervenors on technicalities.

Dr. Abrahamson was asked what alternative he finds to meet energy demands, and replied that the answer lies in achieving lower energy growth rates through conservation. Dr. Bethe explained why it was not realistic to compare our conservation potential with that in Europe. Dr. Abrahamson was also asked what the penalties to the economy would be if his theories were wrong, that is, if conservation were unsuccessful in appreciably lowering energy growth rates and if alternate energy sources were not available to make up the difference. A direct answer to this question was not obtained. Dr. Abrahamson did state that some alternate energy sources could not be relied on due to uncertainties regarding their eventual development. He noted fusion, geothermal, wind power and tidal energy in this regard.

The questions and answers served to highlight the marked difference in opinions among the witnesses regarding the role of breeder reactors. One witness felt that nuclear power and breeder reactors are too costly and too dangerous to be relied on as a major power source; two witnesses believe that the problems raised can be overcome, that the breeder is urgently needed, and that the current development program should continue; and one witness suggested that the breeder is needed, but that the present development program should be accelerated and modified in several respects. These views and those expressed on these questions by the approximately 60 groups and individuals who responded to an earlier letter on energy matters by the subcommittee will be addressed by the subcommittee in its further deliberations on the role of breeder reactors and of the LMFBR program.

REPORT OF SUBCOMMITTEE TO REVIEW LIQUID METAL FAST BREEDER REACTOR

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Friday July 11, 1975

Mr. McCORMACK. Mr. Speaker, in continuation of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Sub-

committee to Review the National Breeder Reactor Program, I have the following report:

Yesterday, the subcommittee in open session received testimony from invited witnesses on the subjects of national electricity production strategy and cost-benefit analysis of the LMFBR program. During that part of the session on the first of these subjects, there was discussion of the total electricity needs of the Nation, the importance of electricity to the well-being of our economy and society, the role of the LMFBR in electricity supply, and decisions and actions that must be taked to meet national energy goals. The cost-benefit of discussion included examination of the economic incentive of LMFBR development, validity—or fallacies—in the assumptions used in cost-benefit studies, economic reasons for and against the early introduction of the breeder, and the relationship of economic arguments to other factors, such as the nuclear fuel resource situation, in assessing the need for the breeder. Testimony on national electricity production strategy was presented by Dr. Chauncey Starr, president of the Electric Power Research Institute. Cost-benefit testimony was presented by Dr. Thomas Stauffer of Harvard University, Dr. Thomas Cochran of the Natural Resources Defense Council, and by Mr. Saul Strauch of the Energy Research and Development Administration. I was pleased that Congressman Frank Horton was able to attend and participate in the questioning of the witnesses.

My opening remarks and a summary of the material presented and the ensuing discussion follow:

OPENING STATEMENT BY THE SUBCOMMITTEE CHAIRMAN

Today the Joint Committee's Subcommittee to Review the National Breeder Reactor Program resumes public hearings. We will hear first from Dr. Chauncey Starr, President of the Electric Power Research Institute, whose testimony will focus in large part upon the role of converter and breeder reactors. He will be followed by the remaining witnesses who will address themselves to the subject of cost/benefit analysis of the liquid metal fast breeder reactor. During that discussion we will receive testimony from Dr. Thomas Stauffer, Harvard University; Dr. Thomas Cochran, Natural Resources Defense Council; and Mr. Saul Strauch, Energy Research and Development Administration.

Dr. Donald Rice, President of Rand Corporation, was invited to participate in the session on cost/benefit analysis, but was unable to do so because of a conflict in schedule. He has, however, submitted a statement which, subject to objection by any member, will be included in the record of these hearings.

I would like to observe that during the 4th of July recess, members of the Subcommittee made a visit to Scotland, England, France, and West Germany to visit breeder reactor facilities and review the programs of the British, French and West Germans. This was a very worthwhile trip, and I believe that the Committee members participating would certainly agree that a great deal was learned. Much of the information derived from the trip presents cause for comparison with the U.S. breeder program. Without dwelling now upon a detailed comparison among the programs, I would simply like to state that the Western European countries are proceeding on an aggressive program intended to bring about early commercialization of the liquid metal fast breeder reactor.

Of particular note is the performance of the Phenix reactor which the French have operated during the past year with a high on-line plant factor. Such performance should be the envy of operators of large fossil plants and light water nuclear plants in this country. In the very near future I plan to report to the House of Representatives the impressions the Subcommittee received during its recent visit to Europe. A copy of that statement will be included as an appendix to the record of these hearings.

Dr. Starr, you may proceed.

Dr. Chauncey Starr, President, Electric Power Research Institute, presented testimony dealing with a strategy for national electricity production. In his testimony Dr. Starr made the following important points:

We must prepare for electricity consumption doubling every ten to fifteen years to the end of the century to insure that our objectives of national security and economic growth can be met.

Given the unacceptability of dependence on foreign oil, for the remainder of the century we have only two realistic indigenous sources for the bulk of the incremental electricity needed—clean fuel from coal, and nuclear power using uranium and plutonium.

None of the advanced concepts of energy production can have any but limited contribution in the next quarter century.

The present proven U.S. uranium resources will be fully needed by the nuclear power plants now in operation or under construction.

The urgency for proceeding with the LMFBR arises from its ability to put a ceiling on cumulative uranium resource demand and accompanying ceilings on additional enrichment plants. Further, the combination of the LWR and the LMFBR provides the best economic system for long-term use of plutonium, and eventually approaches an electricity system independent of fuel resources; i.e. an indefinitely continuous supply of low cost electricity.

There are no credible alternatives to the LWR–LMFBR system at the present time. It is for this reason that fossil fuel short countries, such as France, have chosen this combination to replace all their fossil fuel based electricity generating plants.

All other nuclear alternatives to the breeder (uranium-thorium converters and near breeders) can have only a limited impact on uranium ore need during the next quarter century, and can never achieve the long-term uranium utilization of the breeder. It is important to recognize that the LMFBR is in a state of readiness decades ahead of any other breeder concepts.

The LMFBR is now at the demonstration stage and is ready for the initiation of a near-commercial project.

During the question period following his testimony, Dr. Starr was asked why, if the breeder is expected to produce such a small amount of energy by the year 2000, we need it at all. He replied that the breeder's main contribution comes 10–20 years later, at which time it will play a major role in electricity production. He also noted that every 5 years delay in introducing rhe breeder requires the availability of an additional one million tons of uranium ore, and that there is no assurance this additional ore may be available. With regard to reports that there is a 50% probability of the existence of 13.6 million tons of uranium ore in the U.S. alone, Dr. Starr noted the distinction between assured reserves and possible resources, concluding there was little reason for optimism that uranium supplies would be plentiful.

Dr. Starr was asked about the recent ERDA national energy plan submitted to Congress, which suggested that the development priorities of the LMFBR, solar electricity and nuclear fusion should be equivalent, as all three energy sources will not make significant contributions until after the year 2000. Dr. Starr noted that the development status of the LMFBR is much more advanced than the other two concepts, and that substantial technical or economic questions exist with regard to the feasibility of fusion and the economic viability of solar energy for production of electricity. Dr. Starr, when asked about the possible use of advanced converter reactors such as CANDU, replied that a program for the development of thorium fuel cycle reactors should be pursued jointly with Canada, but noted heavy water reactors cannot supplant the breeder.

With regard to suggestions made by some witnesses at earlier sessions that changes should be made in the LMFBR program, particularly in the CRBR, Dr. Starr replied that, although we might design CRBR differently if we started anew today, by the time the design were finished (3–5 years) it would again be considered "obsolete" by critics. The important point is the contribution CRBR would make if we go ahead with it now. Dr. Starr reported the LMFBR program needs an intermediate sized plant, that CRBR would fulfill its objectives, and that it would be a great mistake to slow it down. He also commented on the relative advantages of overlapping versus sequential steps in major technology programs. Dr. Starr believes that sequential programs have not been successful, and that the planned relationship between FFTF, CRBR and later plants is appropriate. Finally, in response to a suggestion that electricity demand could be reduced substantially by conservation, Dr. Starr replied that, beyond the elimination of waste uses, the potential for conservation is limited without adversely impacting lifestyles, and that it could not replace new energy supply sources as the major means for satisfying future electricity needs.

Dr. Stauffer's testimony was largely based on the cost-benefit study which he, in collaboration with H. Wyckoff and R. Palmer, had performed for Commonwealth Edison Company. The main points made by Dr. Stauffer were 1) the present gross discounted value of the economic savings from a successful breeder program lies between 70 and 100 billion-dollars (in 1975 dollars); 2) the undiscounted reduction in the costs of generating electricity, compared with potentially available alternatives, is \$2.4 trillion (in 1975 dollars) or a savings of 41% at the

busbar; 3) this large economic advantage is not sensitive to other nuclear alternatives such as converters or near-breeder reactors; 4) the advantage is relatively insensitive to the capital cost of the breeder and 5) the economic advantage can be appreciably reduced by delays in breeder development.

Dr. Stauffer went on to say that from their technical-economic analysis, it was their conclusion that development of the breeder reactor must proceed without delay as a form of insurance against our nation being caught with inadequate domestic supplies of cheap uranium. The other main conclusion presented by Dr. Stauffer was that the U.S. should accelerate its program of uranium exploration. Dr. Stauffer's remaining testimony was spent in presenting his rationale and bases for the conclusions reported above.

Dr. Cochran's testimony on cost-benefit analyses reflected the work that he had done with Mr. Speth and Dr. Tamplin of NRDC, which was included in NRDC's report By-passing the Breeder. Dr. Cochran stated that he didn't share Dr. Stauffer's conclusions on the potential benefit-to-cost savings of the breeder. Dr. Cochran reported that the NRDC analysis had used the ERDA model for doing the cost-benefit study but used different inputs in three key areas. These are: 1) the future electrical energy demand; 2) the capital cost differential between the LMFBR and conventional nuclear reactors; and 3) the availability of domestic uranium reserves.

With respect to future electrical demand. Dr. Cochran stated that the value used by ERDA was vastly overinflated. He pointed out that an updated cost-benefit study by ERDA had lowered the future electrical demand by some 25% and that the recently issued ERDA energy plan had reported an even further reduction. On the capital cost differential, Dr. Cochran argued that the reduced capital costs for the LMFBR tha' are anticipated from large scale construction of plants are not consistent with light water reactor experience. Therefore, the NRDC analyses did not include the saving to the same extent as in the ERDA analysis. On the third point, domestic uranium supplies, Dr. Cochran reported the results of studies on potential uranium reserves performed by independent investigators. Their conclusion was that the uranium supply could be significantly greater than that projected for the ERDA base case.

Dr. Cochran said that with their adjustments to the ERDA cost-benefit study, the conclusion he reached was that the LMFBR would not be competitive with existing energy sources until one or two decades after the turn of the century, and thus development of the breeder was premature. Dr. Cochran concluded with a few remarks on alternate energy sources and the contribution they could make in meeting our future energy needs.

Mr. Strauch opened his remarks by reviewing the major conclusions from the recent ERDA cost-benefit study of the LMFBR program. These are that the LMFBR can (1) reduce the cost of electricity to the consumer by as much as 40% shortly after the turn of the century, (2) halve the cumulative requirements of mining uranium and for performing separative work between now and the year 2020, (3) provide a net savings of about $150 billion in cumulative capital requirements to the year 2020, (4) stabilize nuclear power costs at a low level by assuring an unlimited supply of low cost fuel for all reactor types and (5) provide economic benefits far in excess of the R&D costs incurred to develop the concept to the commercial stage.

Mr. Strauch examined the bases for these conclusions, including the current and projected future prices for uranium, the price of nuclear power as a function of the number of LMFBRs, the projected electricity growth rate, and other factors. He reported that about 25 years after the commercial introduction of breeder reactors, fuel self-sufficiency would be attained in the nuclear industry. At that time nuclear plants would generate electricity at the bus bar for about 11 mils per kilowatt hour, or 40% less than it costs today in coal fueled plants.

Mr. Strauch also reported the result of a brief reexamination of the cost-benefit study to determine how the results might vary with recent changes in projection of some of the major parameters. It was shown that if the breeder is available, the impact of rising uranium prices becomes negligible when the system becomes fuel self-sufficient. Without the breeder, uranium price increases are expected to be significant. A similar situation would exist with regard to the cost of separative work; without the breeder, the impact of price increases is greater. The capital cost of LMFBRs and the difference between LMFBR and LWR costs were shown to have a heavy impact on the cost of power from the breeder. A $100 per kw difference after the year 2000 results in an increase in power costs of a single LMFBR of about one mill/kw hr. The effect of lower projected energy demands was also examined.

In his concluding remarks, Mr. Stauch noted, with regard to the need for breeders, that the economics of the LMFBR vs. converter reactors are very much a function of the price of uranium. He noted that uranium prices are likely to increase. He also noted that the sooner the breeder is introduced, the less the total cumulative requirements for uranium and separative work, and the sooner the electric power industry would become fuel self-sufficient.

In the question and answer period, Dr. Stauffer was asked to comment on the statement submitted for the record by Dr. D. Rice of Rand Corporation, who had suggested that the capital cost differential between LMFBRs and LWRs is likely to be substantially higher than the \$100/kw suggested by the AEC. Dr. Stauffer replied that the method used by Dr. Rice in applying learning curves to breeder costs is not entirely reliable, and that if the same procedure were applied to LWRs their costs would show up as \$700–800/kw, which is about twice as high as actual costs. Therefore, Dr. Stauffer reported he disagreed with Dr. Rice's findings.

Dr. Cochran was asked, in comparison to the \$10 billion to be spent on the LMFBR program, how much he expects to be spent on solar energy and fusion. He replied it would be a considerable amount, but could name no definite figure. He voiced his concern that breeder funding would detract from available funds for alternative energy technologies, but the Subcommittee Chairman noted that ample funds were being provided to all technologies. Dr. Cochran went on to say that he does not accept the premise that a delay in the breeder program will result in dollar or uranium availability penalties. In response to a question on whether we will have lost anything if we proceed with the LMFBR program now and then discover additional uranium reserves in the 1980s, Dr. Cochran replied we will lose whatever funds are spent up till that time, and that industry pressures to continue the program will exist even if the need for the program should decrease.

When asked by the Subcommittee Chairman to comment on the approach taken by the Europeans on breeder reactor development, which is more purposeful than that in this country, Dr. Cochran noted that the European economies are different than ours, that their incentives for energy are different, and that the selection of the LMFBR by other countries could be viewed as a common-mode failure, i.e., all were wrong to do so.

Dr. Stauffer was asked a concluding question on uranium ore forecasts, and suggested that the people whom Dr. Cochran cited as being optimistic on uranium availability are not geologists. Dr. Cochran replied by noting that some of the concerns he reported came from the National Petroleum Council. The meeting was adjourned after these questions.

Report of Subcommittee To Review Liquid Metal Fast Breeder Reactor

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Wednesday, July 16, 1975

Mr. McCormack. Mr. Speaker, in continuation of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Subcommittee to Review the National Breeder Reactor Program, I have the following report.

During the period June 28 through July 4, 1975, the subcommittee conducted an onsite review of the British, French, and German breeder reactor programs. I was pleased that Representatives John B. Anderson, Frank Horton, and Andrew J. Hinshaw, and several staff members of the subcommittee were able to accompany me on this trip. The subcommittee's impressions of the Western European breeder reactor program as formulated during this trip are as follows:

IMPRESSIONS OF BREEDER REACTOR DEVELOPMENT IN THE UNITED KINGDOM, FRANCE AND WEST GERMANY BY THE JOINT COMMITTEE ON ATOMIC ENERGY'S SUBCOMMITTEE TO REVIEW THE NATIONAL BREEDER REACTOR PROGRAM

1. The Western European nations are unanimous in their belief that current energy sources are inadequate for future needs, that both coal and uranium must be utilized more heavily than in the past, and that a breeder reactor is needed to make optimal use of uranium resources. The Liquid Metal Fast Breeder Reactor (LMFBR) has been unanimously selected as the most promising breeder concept and is under development by all the industrially advanced nations.

2. The Western European nations have moved forward more aggressively than the United States in committing themselves to breeder demonstration plant construction programs, and have been substantially successful in this mission oriented approach. They have emphasized the construction of prototype (demonstration) plants which will investigate the entire range of operating conditions using existing technology, and are placing major reliance on gaining experience with those plants.

3. For future reactor projects, such as the French Super Phenix and German SNR–2, Western European nations, including Italy and the Benelux countries, are actively cooperating on the governmental and industrial level. SNR–2, for example, will be jointly funded by industries in Germany (RWE–51%), Italy (ENEL–33%) and France (EDF–16%).

4. Cost overruns of varying magnitudes have appeared frequently in Western European breeder programs. Although it does not appear possible to make a direct comparison between actual costs in constant dollars between Western European breeder reactors and those under construction or on order in the United States, it would appear that the British and French, having essentially completed their plants before the recent inflationary spiral, have encountered smaller overruns and have enjoyed much lower total program costs than are projected for the United States and German plants.

5. Funding for the demonstration plants in the Western European nations is almost totally provided by their Federal governments, although varying degrees of industrial involvement were observed in the managment and conduct of new programs.

6. Various similarities and differences in approach were observed in the countries visited, such as in the use of the "tank" or "loop" type reactor system, in the testing of major components in separate facilities vs. obtaining operating experience in plants, and in the selection of fuel reprocessing locations (on-site vs. off-site). However, none of the countries claimed their breeder technology to be inherently better than that of any other country.

7. Breeder demonstration plants in the U.K. and France are designed to operate at conditions more stringent than are believed necessary for commercial plants. For the next generation of plants, certain parameters such as the operating temperature will likely be reduced.

8. Western European nations estimate that there are likely to be 10 million tons of economically recoverable uranium in the world, and are basing their breeder plans on each nation obtaining a "fair share" of this resource.

9. The Western European nations consider plutonium to be a national asset. The potential hazards of plutonium are universally recognized, and operating procedures and engineered projective systems essentially the same as those in place in the U.S. are employed to assure safe handling of plutonium.

10. The Western European countries are anxious to continue and expand technical cooperation and information exchange programs with the U.S. They stated satisfaction in the recently increased U.S. interest in this area.

11. The French have reported extraordinary success with fuel performance in Phenix to date. They state that there has not been a single fuel pin failure among the 20,000 pins irradiated to 55,000 megawatt/days per ton in Phenix during almost one year of operation. They reported a high thermal efficiency (43%), and an availability factor of 77%, including down time for refueling.

12. When panels of experts in European countries (e.g., Royal Commissions) are appointed to resolve technical matters or other points of public or governmental controversary, their findings are considered to be primary inputs into the policy making process, and are generally accepted by the public. This is in marked contrast to the U.S. where the collective work of experts is sometimes viewed with suspicion, and the findings of expert panels are not necessarily considered by some as the most effective basis on which to form public policy.

13. Western European experts believe that the chain of events that must be hyopthezised for a core disruptive accident is so remote that such accidents are not credible. Nevertheless, the reactors in these countries are constructed with the capability to contain a wide range of such non-credible events.

14. Environmental and safety issues were found to play an important part in the development plans of the countries visited. However, the degree of public concern expressed in each country varied, as did the attention to particular issues. For example, the dominant concern in Germany is reported to be the disposal of waste heat from electric generation, both fossil and nuclear. The Germans are, therefore, using waste heat from reactors to heat homes and offices in the vicinity of reactors. It is expected that by 1985 the waste heat from one reactor will be used to heat a town in this fashion as a test of the economic and societal feasibility of this concept.

Report of Subcommittee to Review Liquid Metal Fast Breeder Reactor

HON. MIKE M'CORMACK OF WASHINGTON IN THE HOUSE OF REPRESENTATIVES

Tuesday, July 22, 1975

Mr. McCormack. Mr. Speaker, in continuation of my practice of keeping this body informed of the activities of the Joint Committee on Atomic Energy's Subcommittee to Review the National Breeder Reactor Program, I have the following report:

On July 17, the subcommittee in open session received testimony from Dr. Robert C. Seamans, Administrator of the Energy Research and Development Administration on the subject of ERDA's breeder reactor program. During this session, there was discussion of the comprehensive energy research and development plan which ERDA submitted to the Congress on June 30, the role of the liquid metal fast breeder reactor—LMFBR—in achieving the goals of that program, and the proposed final environment statement on the LMFBR program. on which findings have recently been reached by the Administrator, ERDA. I was pleased that Senators Stuart Symington and James L. Buckley, and Congressman John Young, Teno Roncalio, John B. Anderson, Manuel Lujan, Jr., Frank Horton, and Andrew J. Hinshaw were able to attend and participate in the questioning of the witness.

After welcoming Dr. Seamans at the start of the hearing, I reviewed briefly the sessions held to date by the subcommittee, as reported in previous issues of the Congressional Record. I also read into the record the hearing of the impressions resulting from the subcommittee's recent trip to England, Scotland, France, and West Germany, for the purpose of reviewing the status and future plans of breeder reactor programs in those countries, which appear in the Congressional Record of Thursday, July 17, 1975, at page E3881.

Dr. Seamans then proceeded with his testimony.

In his prepared statement, Dr. Seamans discussed the breeder reactor development program in the context of the energy R. & D. plan which he submitted to the President and the Congress on June 30 and his findings on the environmental statement on the breeder program which he also released on June 30. He cited the energy plan's conclusion that only simultaneous pursuit of all promising technological options can meet our future energy needs.

To meet near-term energy needs, the plan proposes early expansion of existing oil, gas, coal, and uranium energy systems and the application of conservation technologies that will reduce energy consumption. The plan proposes to develop technologies which utilize virtually inexhaustible resources, such as the breeder reactor, solar energy, and fusion, for meeting the long-term—beyond 2000—energy needs.

Particularly important for the breeder, Dr. Seamans pointed out that the plan reaffirms continuation of research, development, and demonstration of the breeder reactor as a priority matter.

Dr. Seamans said that his review of the proposed final environmental statement amply demonstrates the need to continue research, development, and demonstration of the LMFBR concept. He went on to point out that there is no presently available or prudent alternative to this course of action.

Dr. Seamans said there are several significant problems, including in particular those related to reactor safety, safeguards, and waste management, which remain unresolved. He said that although these problems must be resolved satisfactorily before the LMFBR can be commercialized, the record strongly suggests that the problems identified in the LMFBR concept are amenable to solution, wholly or partially, by a continuation of the breeder program.

Dr. Seamans anticipated that a final impact statement will be issued within about 3 months.

Dr. Seamans said that he has requested certain funding reductions in the LMFBR program, including the Clinch River breeder reactor project, because of delays in the breeder development program caused by licensing and environmental issues.

Dr. Seamans mentioned that there has been speculation that these funding changes indicate a lessening of resolve on ERDA's part to continue the breeder program. He said such speculation is erroneous and that the importance and priority of the LMFBR program remain unchanged.

Dr. Seamans also pointed out that the National Academy of Sciences will be conducting a study that will center on public concern about nuclear energy and the degree to which the Nation should rely on nuclear power.

In the questioning period following his testimony Dr. Seamans was asked what he thought were the chances that the safety, environmental, and safeguards problems relating to the breeder could be solved. He said there was a 90- to 95-percent chance of success.

In response to a question on whether he was downgrading the breeder, Dr. Seamans said he was not and that he intends to vigorously pursue the program.

In response to a question on why the Europeans are ahead of the United States in breeder development, Dr. Seamans said the breeder is a complicated and difficult project, the success of which depends on such factors as starting date, budget support, and clearly designated responsibility for the program. He said he is in the process of clearing up ambiguities which existed with the utilities' involvement and establishing clear project direction. He said that in about 1½ months he would have new budget requests reflecting the program changes he is making.

In response to questions relating to why the United States cannot just build a Phenix on the Clinch River site instead of continuing development of our own program, Dr. Seamans said it is not possible to just buy a foreign technology and expect it to work easily. Capabilities in manufacturing, licensing, and operating must be built up domestically and this requires the United States to build a demo plant. He said he would be reluctant to proceed into the next century relying on another country's breeder technology.

In response to a question as to how far we are behind the Europeans in our breeder program, Dr. Seamans said we are not far behind. We have a broad based program with many trained people to carry out designs and to test, manufacture, and construct our plants.

One member expressed his concern that we not study the breeder to death. Dr. Seamans said that progress is achieved by doing and that the Clinch River plant must be constructed to bring the whole program together.

Dr. Seamans was also asked whether ERDA had made any attempt to use foreign facilities to test breeder components. He said he plans to look into this on his upcoming trip to Europe.

It was pointed out to Dr. Seamans that in spite of a host of reports refuting the hot particle issue, the ERDA Internal Review Board which studied the PFEIS still considered this issue unresolved. Dr. Seamans said he would consider the body of scientific knowledge represented in those studies in making his final decisions.

In response to a question as to the reason for delays in the program, witnesses reported that the need for licensing approval was a primary factor. They stated that the current need for Nuclear Regulatory Commission to consider two designs for the CRBR, one with and one without a core catcher, was an important consideration in the start of construction—receipt of a limited work authorization—now being projected to occur not before August 1976, about 1 year later than had been previously anticipated.

APPENDIX 3

REPORT ON ON-SITE REVIEW OF FOREIGN PROGRAMS

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., July 15, 1975.

Senator JOHN O. PASTORE,
Chairman, Joint Committee on Atomic Energy,
Washington, D.C.

DEAR MR. CHAIRMAN: The Joint Committee on Atomic Energy's Subcommittee To Review the National Breeder Program conducted an on-site review of the British, French, and German breeder reactor programs from June 28, through July 4, 1975. Congressmen Anderson, Horton, and Hinshaw, and several staff members of the Subcommittee accompanied me. The purposes of the trip were to study the goals, approach, performance, status and future plans for the LMFBR programs in the countries visited, to determine similarities and differences between the West European and U.S. breeder development programs, and to ascertain what, if any, changes to the U.S. program might be called for in light of what would be learned from the West European programs.

The Subcommittee visited Dounreay, Scotland; Manchester, England; Marcoule and Cadarache, France; and Bonn and Bensberg, West Germany. We were afforded a close-up examination of the British prototype fast reactor and the French Phenix, both of which were operating at the time, and a wide range of support facilities in the countries visited. A detailed itinerary is provided in enclosure one.

The Subcommittee found that nearly all countries in Western Europe are involved in the development of the Liquid Metal Fast Breeder Reactor (LMFBR), either through cooperative agreements or through their own programs. They are unanimous in their belief that the LMFBR is necessary to meet future energy demands. All breeder demonstration projects in the countries visited appear to be ahead of the comparable program in the United States. For example, yesterday, the French completed one year of full power operation of the 250 MWe Phenix reactor, and report extraordinary operating performance for the period. The British have completed construction of a 250 MWe LMFBR which has achieved criticality. They are presently conducting reduced power testing while searching for small leaks in the steam generating system. The Germans have a 300 MWe LMFBR under construction, and project its completion by 1979. A more complete report of the Subcommittee's findings is provided in enclosure two, entitled "Impressions". These impressions will be printed in the Congressional Record of July 16, 1975.

The information obtained from the observations, discussions, and documentation acquired during this trip will be used by the Subcommittee in the preparation of its final report on the U.S. breeder program, which we plan to submit to you, and through you to the Congress in early September. The extensive documentation obtained during the trip will be included in the permanent record of the Subcommittee.

I would be pleased to brief you or answer any questions you might have on the trip or our impressions of the Western European breeder programs.

Sincerely yours,

MIKE McCORMACK,
Chairman, Subcommittee To Review the National Breeder Reactor Program.

Enclosures:
1. Chronology of Trip.
2. Impressions.

[ENCLOSURES]

SUBCOMMITTEE TO REVIEW THE NATIONAL BREEDER REACTOR PROGRAM

CHRONOLOGY OF TRIP TO EXAMINE FOREIGN BREEDER FACILITIES

The Joint Committee's Subcommittee to Review the National Breeder Reactor Program visited European breeder facilities from June 28 through July 4, 1975. Following is a chronological summary of the facilities visited.

On Monday, June 30, the Subcommittee visited the Dounreay Experimental Reactor Establishment which is situated on the North Coast of Scotland. During the visit, the Subcommittee toured the Dounreay Fast Reactor (DFR), which was the first European breeder reactor to produce electricity. In addition to producing small quantities of electricity, the DFR is now being used as a major fuel and materials test facility.

The Subcommittee also toured the 250 MWe Prototype Fast Reactor (PFR). Construction of the PFR has been completed and the reactor is now undergoing low power testing. Lack of time prevented the Subcommittee from visiting the DFR fuel fabrication and reprocessing facilities which are also operational at the Dounreay site. However, the Subcommittee did hold beneficial introductory discussions on the United Kingdom's breeder program, including, specifically, how the DFR and PFR fit into that program.

On Tuesday, July 1, the Subcommittee met at Risley (Manchester, England) with representatives of the United Kingdom Atomic Energy Authority and the Medical Research Council's Committee on Protection against Ionizing Radiation. The topics discussed included breeder development strategy, safety and environmental concerns, and long range planning.

On Wednesday, July 2, the Subcommittee visited the French breeder facilities at Marcoule in the morning and the Cadarache Nuclear Research Center in the afternoon. At the Marcoule facility, the Subcommittee visited the Phenix, a 250 MWe LMFBR, which completed its first year of full power operation on July 14, 1975.

At the Cadarache facility, the Subcommittee visited the 40 MWe Rapsodie reactor, which is now a testing facility for fast neutron reactor fuel using sodium as the coolant. While at Cadarache, the Subcommittee also visited the Phenix component test facility, sodium test-rigs, fuel fabrication facilities, and spent fuel processing and handling facilities.

On Thursday morning, July 3, the Subcommittee met with representatives of the Federal Agency for Research and Technology in Bonn, Germany; in the afternoon, the Subcommittee met at the headquarters of Interatom, at Bensberg, West Germany, with West German reactor manufacturers, utilities, and researchers.

Impressions of Breeder Reactor Development in the United Kingdom, France and West Germany by the Joint Committee on Atomic Energy's Subcommittee To Review the National Breeder Reactor Program

(1) The Western European nations are unanimous in their belief that current energy sources are inadequate for future needs, that both coal and uranium must be utilized more heavily than in the past, and that a breeder reactor is needed to make optimal use of uranium resources. The Liquid Metal Fast Breeder Reactor (LMFBR) has been unanimously selected as the most promising breeder concept and is under development by all the industrially advanced nations.

(2) The Western European nations have moved forward more agressively than the United States in committing themselves to breeder demonstration plant construction programs, and have been substantially successful in this mission oriented approach. They have emphasized the construction of prototype (demonstration) plants which will investigate the entire range of operating conditions using existing technology, and are placing major reliance on gaining experience with those plants.

(3) For future reactor projects, such as the French Super Phenix and German SNR–2, Western European nations, including Italy and the Benelux countries, are actively cooperating on the governmental and industrial level. SNR–2, for example, will be jointly funded by industries in Germany (RWE–51%), Italy (ENEL–33%) and France (EDF–16%).

(4) Cost overruns of varying magnitudes have appeared frequently in Western European breeder programs. Although it does not appear possible to make a direct comparison between actual costs in constant dollars between Western European breeder reactors and those under construction or on order in the United States, it would appear that the British and French, having essentially completed their plants before the recent inflationary spiral, have encountered smaller overruns and have enjoyed much lower total program costs than are projected for the United States and German plants.

(5) Funding for the demonstration plants in the Western European nations is almost totally provided by their Federal governments, although varying degrees of industrial involvement were observed in the management and conduct of the programs.

(6) Various similarities and differences in approach were observed in the countries visited, such as in the use of the "tank" or "loop" type reactor system, in the testing of major components in separate facilities vs. obtaining operating experience in plants, and in the selection of fuel reprocessing locations (on-site vs. off-site). However, none of the countries claimed their breeder technology to be inherently better than that of any other country.

(7) Breeder demonstration plants in the U.K. and France are designed to operate at conditions more stringent than are believed necessary for commercial plants. For the next generation of plants, certain parameters such as the operating temperature will likely be reduced.

(8) Western European nations estimate that there are likely to be 10 million tons of economically recoverable uranium in the world, and are basing their breeder plans on each nation obtaining a "fair share" of this resource.

(9) The Western European nations consider plutonium to be a national asset. The potential hazards of plutonium are universally recognized, and operating procedures and engineered projective systems essentially the same as those in place in the United States are employed to assure the safe handling of plutonium.

(10) The Western European countries are anxious to continue and expand technical cooperation and information exchange programs with the United States. They stated satisfaction in the recently increased U.S. interest in this area.

(11) The French have reported extraordinary success with fuel performance in Phenix to date. They state that there has not been a single fuel pin failure among the 20,000 pins irradiated to 55,000 megawatt/days per ton in Phenix during almost one year of operation. They reported a high thermal efficiency (43%), and an availability factor of 77%, including down time for refueling.

(12) When panels of experts in European countries are appointed to resolve technical matters or other points of public or governmental controversy, their findings are considered to be primary inputs into the policy making process, and are generally accepted by the public. This is in marked contrast to the United States where the collective work of experts is sometimes viewed with suspicion, and the findings of expert panels are not necessarily considered by some as the most effective basis on which to form public policy.

(13) Western European experts believe that the chain of events that must be hypothesized for a core disruptive accident is so remote that such accidents are not credible. Nevertheless, the reactors in these countries are constructed with the capability to contain a wide range of such non-credible events.

(14) Environmental and safety issues were found to play an important part in the development plans of the countries visited. However, the degree of public concern expressed in each country varied, as did the attention to particular issues. For example, the dominant concern in Germany is reported to be the disposal of waste heat from electric generation, both fossil and nuclear. The Germans are planning, therefore, to use waste heat from reactors, as the British are now doing, to heat homes and offices in the vicinity of reactors. It is expected that by 1985 the waste heat from one reactor will be used to heat a town in this fashion as a test of the economic and societal feasibility of this concept.

APPENDIX 4

BACKGROUND INFORMATION ON BREEDER REACTORS[1]

ROLE OF BREEDERS IN U.S. ENERGY ECONOMY

While present-day reactors can provide a vital contribution to meeting the Nation's electrical energy needs over the short-term, the breeder reactor is necessary if fission energy is to contribute to the Nation's long-term energy needs.

ROLE OF BREEDERS

The LWR can utilize only a small percentage of the energy available in uranium (1 to 2%) because it depends upon the fission of the uranium isotope U^{235} which exists at a concentration of less than 1% in natural uranium. In order for an LWR to operate, the concentration of U^{235} in its uranium fuel must be increased by a factor of almost 5, from 0.7% to about the 3 to 3½% enrichment level. For each unit of enriched product, a much larger amount of uranium depleted in U^{235} is generated as "tails" at the enrichment plant.

During operation of LWR's, only a small fraction of the fuel can be fissioned before the fissile content of the core falls to an unusable level of between 0.6 and 1.0% U^{235} depending upon the LWR type and on the fuel management method being used.[2] With such continuing inefficient use of uranium resources, it is clear that the Nation's supply of economically priced ore could be rapidly dimished; and indeed, there is some concern about the availability of domestic uranium resources at an attractive price to meet the longer term requirements.

Breeder reactors could economically use the large domestic resources of low-grade uranium ore, which could not be used in LWR's without considerably higher power costs, and, in addition, can economically recover much of the energy available in the depleted uranium tails. Thus, in a nuclear power economy using a mix of both fast breeders and LWR's, no appreciable amount of potential energy would be lost as a result of the relative inefficiency of LWR's with respect to fuel utilization.

[1] Obtained from LMFBR Program Environmental Impact Statement, ERDA, Vol. I, pp. 21–23.

[2] These numbers do not apply to reactors operating on the thorium—U-233 fuel cycle such as the high-temperature gas cooled reactor (HTGR) now available as an option to U.S. utilities. HTGRs are designed to operate with U-233 generated from thorium mixed with some U-235, and they should be able to extract 4 to 5% of the total available energy.

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TYPES OF BREEDERS

There are two general kinds of breeder reactors—"fast breeders" and "thermal breeders."

The thermal breeder, employing slow neutrons, uses the thorium-232-uranium-233 cycle (usually called the thorium cycle). The fast breeder, employing more energetic neutrons, uses the uranium-238-plutonium-239 cycle (the uranium cycle).

Since the fast breeder utilizes the uranium-plutonium fuel cycle, it complements the light water reactors which also use this cycle. The transition from the light water reactors to the fast breeders is projected to be a natural and orderly process. The plutonium produced by the light water reactors will be used to fuel the fast breeders until they have operated sufficiently long enough to provide the excess plutonium needed for supporting a completely self-sufficient fuel cycle. After a plutonium production rate sufficient to sustain the expanding breeder reactor economy is attained, the fast breeder reactors could function as producers of fuel for other fission reactors. They could provide plutonium for plutonium recycle in LWRs or, by replacing uranium in the blankets with thorium, could provide U^{233} for use in HTGR's.

Based on its potential economics, the interest of the reactor manufacturers and electric utilities, and the base of technology already available, the liquid metal fast breeder reactor (LMFBR) has been selected as the Nation's priority fast breeder program. Several other major industrial nations—the United Kingdom, Germany, France, U.S.S.R., Japan—have similarly chosen the LMFBR as a priority effort in their nuclear programs. Additional information on this reactor, its benefits, and its environmental impact is provided in other sections of this Statement.

Although priority has been given to the LMFBR, research and development programs are being conducted involving several other types of breeders. These include two thermal breeders: the light water breeder reactor (LWBR)—which is intended to significantly improve fuel utilization in current and future pressurized light water reactors—and the molten salt breeder reactor—which involves the use of a high temperature circulating fuel in which uranium and thorium are dissolved in LiF-BeF_2 carrier salts. Another program now receiving accelerated effort is directed toward the development of the high breeding gain gas-cooled fast breeder reactor (GCFR) which utilizes helium gas as a coolant rather than the sodium used in the LMFBR.

APPENDIX 5

ANALYSIS OF RELIANCE ON FOREIGN TECHNOLOGY BY THE LMFBR PROGRAM REVIEW GROUP[1]

TOPIC III. STATEMENT OF THE ISSUE

"What is the relationship between the U.S. LMFBR program and foreign LMFBR activities, and what practical alternatives, if any, do these programs offer for the U.S. program?"

FINDINGS AND CONCLUSIONS

There are active LMFBR development programs in several foreign countries, including the United Kingdom, France, West Germany, Japan and the Soviet Union. The Review Group was given a description of the activities and plans in each of these countries as they are known. These foreign programs are summarized in Attachment 7.[2] In general, while there are some differences in approach and emphasis, all of the programs either contain or plan many of the same elements as are in the long-range U.S. LMFBR program. The French have in operation a 250 MWe LMFBR plant, Phenix; they plan to construct a 1200 MWe plant, Super Phenix, and to have it operating by 1985. The Soviets have in partial operation a 350 MWe plant and have a 600 MWe plant under construction. The other programs also either have in operation, under construction or planned, intermediate-sized LMFBR plants, and all are aimed ultimately at commercial-size plants in the thousand megawatt or greater range.

With this situation prevailing, it is obviously appropriate to consider whether any savings can be made either in the Clinch River Project or in the LMFBR program as a whole by expanded interaction or greater utilization of the foreign programs. The Group directed its attention to the methods by which foreign programs might interact with the U.S. programs, primarily in the context of the achievement of the LMFBR program's technological and commercialization objectives.

Of the many courses of action conceivable, the Group chose to consider the following as representative of essentially the complete spectrum:

1. Cooperate with foreign countries to the extent of obtaining technological information from their programs.
2. Purchase from foreign sources LMFBR components that have been developed in foreign programs for testing and/or usage in the U.S. plants.

[1] Report of the LMFBR Review Group, ERDA-1, January 1975.
[2] Not included with material printed herein.

3. Negotiate with one or more of the countries planning an intermediate-size LMFBR power plant for a cooperative program to design and construct such a plant, to be located either in the United States or abroad.

4. Rely on obtaining information from a foreign plant, e.g., the Phenix plant, instead of building an intermediate-size plant in the United States.

5. Depend totally on foreign sources for LMFBR technology and power plants.

In considering these alternatives, the Group noted that there are certain essential requirements which would have to be satisfied under any course using foreign technology. These requirements involve technological information, operational experience, the development of industrial fabrication capabilities, including quality control and reliability, and the incorporation of U.S. safety requirements and standards into the final products.

The Group's views with respect to each of these options are as follows:

1. Maximum benefit should be made of the scientific and technological information being developed in other countries. It is noted that there are formal or informal cooperative exchanges of information with all of the LMFBR countries. The attempt is made to obtain as much benefit from foreign programs as the United States gives in terms of its own information to the foreign programs. The Group believes this approach is the proper one. However, there may be instances in which it is worth paying for foreign data and the use of test facilities. There may be foreign projects for which arrangements based on *quid pro quo* or financial payment should be made to enable the United States to place technical staff in the program under foreign supervision to obtain not only information but a full working knowledge of the reactor system. Such instances should be considered on a case-by-case basis.

2. The U.S. program should consider purchase of foreign components whenever they promise to meet the necessary requirements for the U.S. LMFBR program and can be purchased at reasonable prices. There is no inherent need, in the Group's view, for every component to be U.S.-developed and manufactured. As a practical matter, this course is the one that is normally followed in industrial design and construction projects.

3. The design, development, fabrication, construction and operation of an LMFBR powerplant of the intermediate developmental size is an extremely difficult and complex undertaking. To develop a fully cooperative program and organization for such a project would in the Group's judgment be a very difficult and time consuming task, with uncertain results. There is no simple way in which a plant can be segmented for assignment to several individual countries for development and manufacture. One approach would consist of a fully integrated organization with lead roles necessarily of a committee nature rather than having control assigned to a single individual. It is not clear that U.S. interests, including those of the reactor manufacturers and utilities, could be served in such combination.

A variation would be to assign to one country the lead role with others simply participating and contributing to that lead country's activities. For the United States to defer its activities to another country's lead would be close to alternative 4 discussed below. Alternatively, there is no evidence that other countries would be willing to participate in a U.S. project as "junior" partners, though such should not be precluded.

4. Assuming that the United States, at some cost to be determined, could send teams of specialists to Phenix or another reactor to obtain complete information on the design and operation of the plant, the United States would thereby obtain only technical information, but no industrial base. It cannot by such a mechanism generate the detailed technological and industrial base that is, in the Group's view, an essential step toward commercialized LMFBR technology. The purpose of developing, constructing, and operating the Clinch River plant is not to determine whether a breeder reactor of intermediate size can be made to work, but rather to gain experience with an LMFBR under utility operating conditions and to develop the industrial capabilities and know-how necessary for such a plant to work reliably and with good performance. CRBR's size is set by the limit to scale-up of industrial capability for component manufacture which could occur with prudent risk. It extends the basic industrial potential for manufacturing LMFBRs in the United States. None of those features could be realized under such an arrangement with Phenix or other foreign programs. In the Group's judgment, this alternative would be the same essentially as the United States program moving directly to a full size plant.

5. Conceptually it might be possible for the United States to be totally dependent on foreign LMFBR programs for breeder technology. This, of course, assumes that the foreign programs would lead to successful conclusions on a timely basis and that the foreign countries would share their technology, presumably at some cost.

There is a substantial risk in such a course because it would involve dependence on foreign sources for an as yet undeveloped technology For so important a commodity as energy, a strong United States capability is essential.

In considering this alternative, there are important factors beyond questions of technical and programmatic feasibility and attractiveness. They include (1) future balance of payments implications if this country were an importer rather than a potential exporter of this technology, and (2) the question of depending on foreign countries for an important high technology effort in the framework of U.S. high technology strength and U.S. industrial development. The Group was unable to address these issues though they may be overwhelming in importance.

In summary, the Group concludes that the technically practicable alternatives for foreign interactions are alternatives 1, 2, and 5. Alternatives 1 and 2 can be pursued without major new policy initiatives, but they cannot be expected to save any large identifiable amount of U.S. effort. Alternative 5 would, in effect, lead to the termination of the U.S. LMFBR activities with uncertain, but potentially very serious, consequences for U.S. energy self-sufficiency.

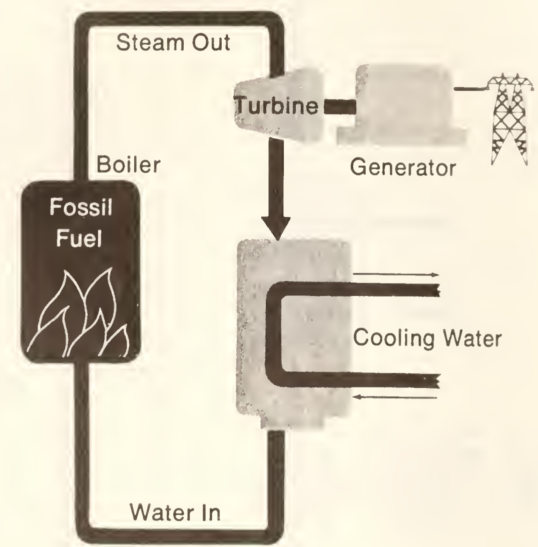
APPENDIX 6

AN INTRODUCTION TO ADVANCED NUCLEAR REACTORS

The following materials were selected from "Advanced Nuclear Reactors: ERDA-46—September 1975," produced by the Division of Reactor Research and Development, U.S. Energy Research and Development Administration.

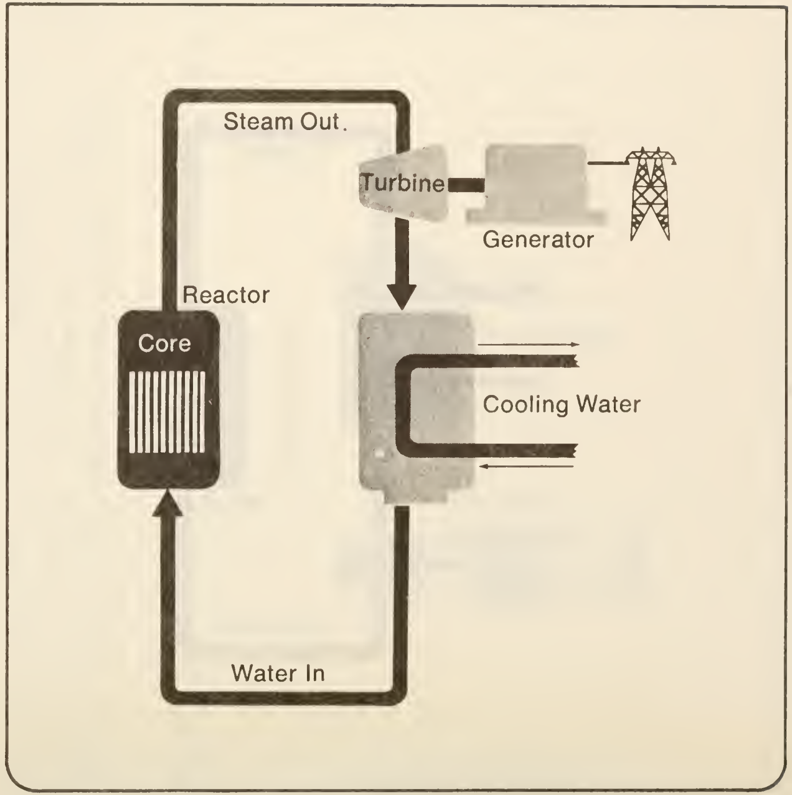
Fossil Fuel Plants

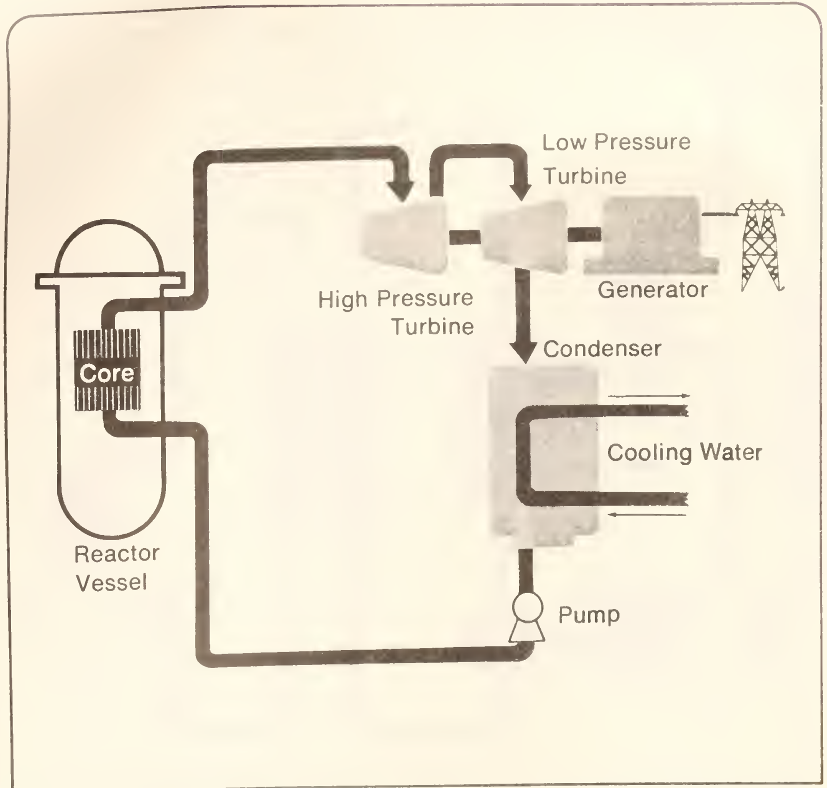
Nuclear reactors generate electricity in much the same way as fossil fuel plants. In fossil fuel plants, fuel is burned to produce heat. The heat is transferred to a boiler to produce steam. The steam runs a turbine to produce electricity.



Nuclear Plants

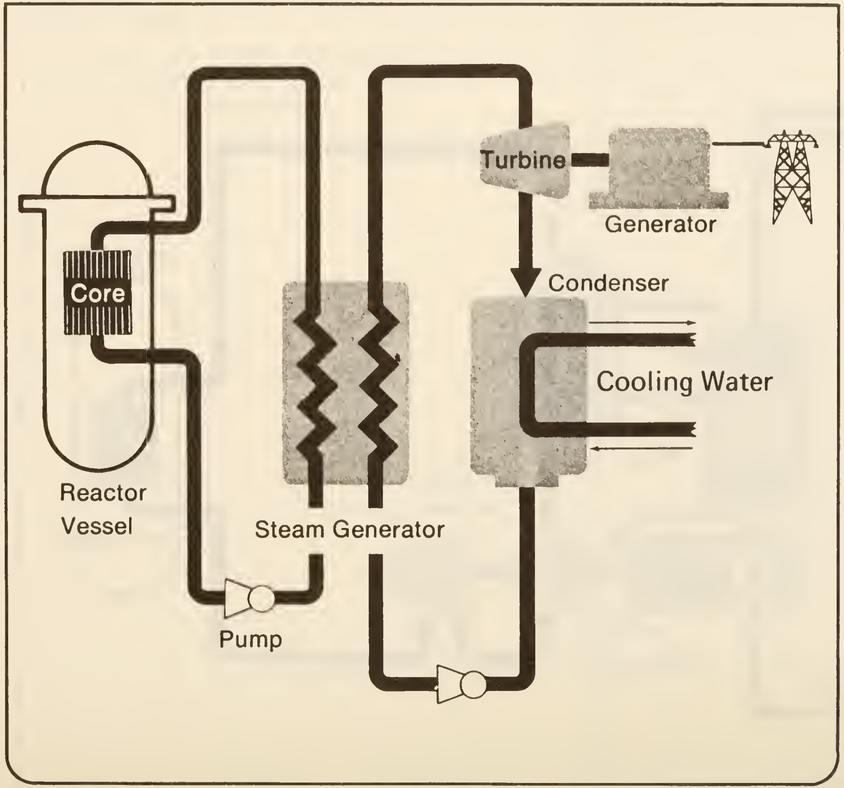
The core of a nuclear plant performs the same function as the boiler of a fossil fùel plant—it generates heat.





Boiling Water Reactors

In the U.S., there are two distinct types of Light Water Reactors. In both, the heat extracted from the core is used to make steam. In a boiling water reactor (BWR) the steam is generated directly by the heat from the core. This steam runs a turbine to generate electricity. Thus, it is a "direct-cycle" system. The BWR operates at a pressure of 1000 pounds per square inch and a temperature of 545°F.



Pressurized Water Reactors

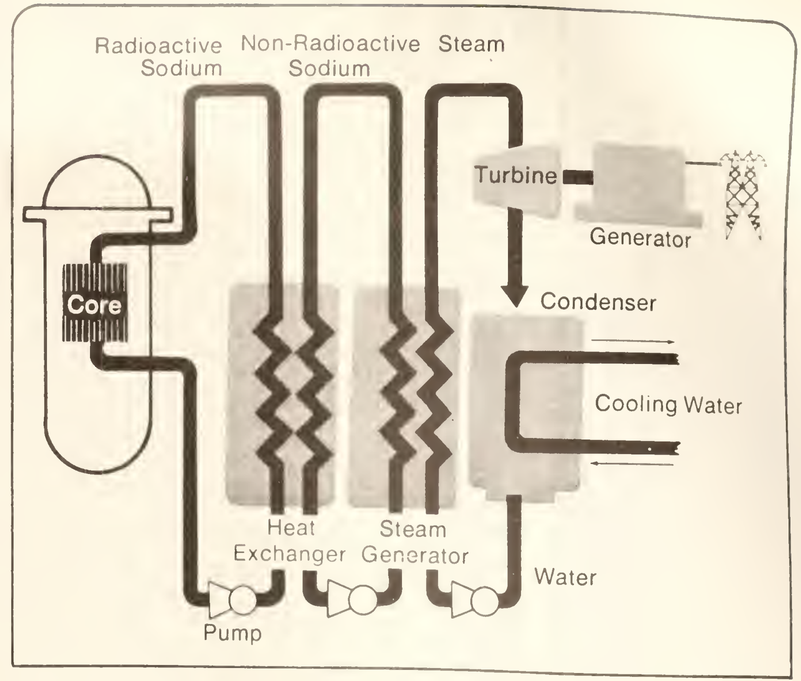
In a pressurized water reactor (PWR), the water heated by the core is circulated through a closed system, called a "loop." This first loop carries the heat from the core to a steam generator where the heat is transferred to a second loop. It is in this second loop that the steam is generated to produce electricity. The PWR operates at 2250 pounds per square inch and 600°F.

LMFBR Characteristics

Some of the characteristics of the LMFBR should be noted. The LMFBR operates on a uranium/plutonium fuel cycle; uranium-238 is converted to plutonium-239 which is the fissile material (the material that fissions) in the reactor. The fuel is formed into pellets for insertion into the reactor. These pellets are a uranium/plutonium oxide mixture. The coolant in the LMFBR is liquid sodium. Because sodium is an excellent heat transfer fluid, the reactor can operate at high temperature and low pressure. As has been mentioned, the LMFBR operates at a high thermal efficiency—about 40%.

LMFBR Design

The primary sodium loop is radioactive. It carries away heat generated by the core. The heat is then exchanged with a second loop of sodium, which is non-radioactive. The point of interchange is the intermediate heat exchanger. The heat from the second loop is used to generate steam for electricity. The secondary sodium loop is a safety precaution, allowing the radioactive sodium to be entirely isolated within the primary containment building.



GLOSSARY

Breeder.—A nuclear reactor that produces more fuel than it consumes. Breeding is possible because of two facts of nuclear physics:

1. Fission of some atomic nuclei produces more than one neutron for each nucleus undergoing reaction. Hence, one neutron can be used to sustain the fission chain reaction and the excess neutrons can be used to create—breed—more fuel.
2. Some nonfissionable nuclei can be converted into fissionable nuclei as a result of capture of a neutron. Nonfissionable uranium-238, for example, can thus be bred into fissionable plutonium-239.

Breeder reactors are divided into two types: *fast breeders*, which use high energy neutrons, and *thermal breeders*, which use neutrons of lower energy.

Breeding ratio.—A measure of the efficiency of a breeder reactor. Defined as the number of new fissionable atoms produced per atom of fissionable material consumed.

British thermal unit (Btu).—The amount of energy necessary to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Converter.—A nuclear reactor that consumes more fuel than it produces.

Critical mass.—The minimum amount of fissionable material, such as uranium-235 or plutonium-239, that is required to produce a self-sustaining nuclear chain reaction, once it has been initiated by an external source of neutrons.

Doubling time.—The time required for a breeder reactor to produce as much fissionable material as the amount normally contained in its core, plus the amount tied up in its fuel cycle—fabrication, cooling, processing, and transporting—and thus to be able to support the operation of an additional reactor of the same kind.

Enrichment.—The process of increasing the concentration of uranium-235 in uranium from the naturally occurring level of about 0.7 percent to a higher concentration. The principal process of enrichment is gas diffusion. A second process, the gas centrifuge, is also receiving much attention.

Fertile.—Those atoms that can be converted into nuclear fuel (fissionable atoms). For example, uranium-238, plutonium-240 and thorium-232 are fertile materials.

Fissile.—Fissionable, capable of fission or of being a nuclear fuel.

Fission.—The splitting of atomic nuclei into two or more nuclei of lower atomic weight and whose aggregate mass is less than that of the original nucleus. The process is initiated by the capture of a neutron by the nucleus of the fissionable atom and is accompanied by the emission of one to about three neutrons.

Fusion.—The combination of two atomic nuclei to yield one larger nucleus whose mass is less than the aggregate mass of the original nuclei; the lost mass appears as energy in the same manner as in fission.

Gigawatt.—1,000 megawatts or 1,000,000 kilowatts.

Laser fusion.—A proposed concept in which high temperature and pressure required for initiating fusion are produced by bombarding *fuel pellets* (frozen deuterium and tritium) with intense bursts of electromagnetic radiation from one or more lasers.

Megawatt.—1,000 kilowatts.

Moderator.—A substance used to slow neutrons to a speed at which there is a higher probability of initiating fission in a nuclear reactor. The neutrons lose energy by colliding with the nuclei of the moderator. The most commonly used moderators include graphite, water, heavy water (deuterium oxide), and beryllium.

Neutron.—An uncharged (neutral) elementary particle with a mass slightly larger than that of a proton. Because it has no electrical charge, the neutron is able to penetrate the dense negatively charged electron cloud on an atom and interact with the positively charged nucleus.

Quadrillion.—A thousand trillion, or the number 1 followed by 15 zeros.

Radioactivity.—The spontaneous disintegration of the nucleus of an atom with the emission of corpuscular or electromagnetic radiation. These emissions are of three principal types, called alpha, beta, and gamma. Alpha radiation is composed of positively charged helium nuclei (two protons and two neutrons) ejected with a velocity 5 to 7 percent that of light. Beta radiation is composed of negative electrons ejected with velocities which may approach the speed of light. Gamma radiation is uncharged electromagnetic radiation similar to X-rays. Although gamma radiation is approximately 100 times more penetrating than that of beta radiation and about 1,000 times more penetrating than that of alpha radiation, it is not necessarily the most dangerous since ingestion must be considered.

Reactor.—An assembly of nuclear fuel capable of sustaining a controlled fission chain reaction.

Tails.—The portion of the enrichment process stream which is low in uranium-235 content (below the 0.7% as found in nature, usually 0.2 to 0.3%).

Transuranic.—An element in the periodic table of higher atomic number than uranium, such as plutonium, neptunium, et cetera.

LIST OF ABBREVIATIONS

AEC	Atomic Energy Commission
API	American Petroleum Institute
BRC	Breeder Reactor Corporation
CE	Commonwealth Edison
CRBR	Clinch River Breeder Reactor
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration
FEA	Federal Energy Administration
FFTF	Fast Flux Test Facility
FPC	Federal Power Commission
GCFR	Gas-Cooled Fast Reactor
GNP	Gross National Product
HTGR	High Temperature Gas Reactor
LMFBR	Liquid Metal Fast Breeder Reactor
LWR	Light Water Reactor
Mb/d	Million barrels per day
MSBR	Molten Salt Breeder Reactor
NAS	National Academy of Sciences
NCBR	Near-Commercial Breeder Reactor
NRC	Nuclear Regulatory Commission
NRDC	Natural Resources Defense Council
NURE	National Uranium Resource Evaluation
PCTF	Plant Component Test Facility
PFES	Proposed Final Environmental Statement
PMC	Project Management Corporation
SAREF	Safety Research Facility
SCTI	Sodium Components Test Installation
SIPI	Scientists' Institute for Public Information
TVA	Tennessee Valley Authority
USGS	United States Geological Survey

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